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GENETIC PSYCHOLOGY MONOGRAPHS

Child Behavior, Animal Behavior, and Comparative Psychology

FAMILY RESEMBLANCES IN VERBAL AND NUMERICAL ABILITIES*

From the Department of Psychology of the University of Minnesota

By

HAROLD DEAN CARTER

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I

INTRODUCTION

A. The Problem

This study is concerned with family resemblances in verbal and numerical abilities as measured by vocabulary tests and arithmetical computation tests. No attempt is made to measure every aspect of either verbal ability or numerical ability; our concern has been to obtain highly reliable measurements of performances on these two types of tests, and then to use the vocabulary test results as indicative of verbal ability, and the computation test results as indicative of numerical ability. Vocabulary tests are largely represented in good intelligence tests, and are probably the best single measures of verbal ability; performance in these tests is highly diagnostic of scholastic success. Arithmetic tests are probably the best measures of numerical ability; of the two types of arithmetic tests, the computation tests measure an ability more independent of verbal ability. We are, for the moment, interested in the abilities measured by these tests, rather than in any hypothetical capacity of which they are perhaps only a part, and throughout the entire discussion the names arithmetic ability and vocabulary ability refer to performance on these tests.

B. Summary of Literature

E. L. Earle (9), in 1903, measured the resemblances of siblings in spelling ability. In one school system

the average fraternal resemblance measured by a correlation based on 191 pairs was .25. In this case the environment of the different members of each pair was far from constant, and the coefficient is unduly low. In the case of another school system, where training was more uniform and the population more stable, the coefficient based on 196 pairs was .51, which is more in agreement with later studies of sibling resemblances.

In 1903 Karl Pearson (37, 38) published results of extensive investigations based on between three and four thousand test records. The numbers of cases, while different for different correlations, are all very large. The correlations between siblings in physical traits such as stature, span, cubit, and eye-color averaged slightly more than .50 for adults. For school children the average correlation of head measurements of siblings was approximately .51, and for a variety of physical traits about .52. In the case of mental traits such as vivacity, assertiveness, introspection, popularity, conscientiousness, temper, ability, and handwriting, the average correlation for siblings was about .52. Pearson also published data showing that the correlations of fathers and sons in traits such as stature, span, length of forearm, and eye-color were on the average about .47, which agrees with the results found for physical traits in various studies of lower animals. He concluded that, in general, mental traits are inherited in much the same manner, and to the same degree, as are physical traits.

F. A. Woods (64) (1906) rated 671 members of

European Royalty in intellect and in morals, on a scale of one to ten. These ratings yielded a correlation of .30 for parents and offspring in intellect, the calculation being based upon 504 pairs. For morals, the parent-child correlation was also .30. Woods presents arguments to indicate that these correlations are probably little influenced by environmental factors, especially in the case of intellect.

In 1907 D. A. Heron (25) published the results of his statistical study of insanity. Dr. Urquhart, Superintendent of the James Murray's Royal Asylum, Perth, furnished him with 331 rather complete family histories, covering two generations in almost all cases, and three or four generations in some cases. This made possible comparison of parents and children in insanity. The parent-child correlations ranged from .52 to .62, with a probable true value of about .57. The coefficients of fraternal resemblance ranged from .45 to .55 with a probable true value of .50. These results are compared with those of similar studies of pathological, physical, and psychical characters, and the agreement is very good. Heron concluded that the "insane diathesis" is inherited to the same extent as are other pathological traits, or physical or psychical traits.

In 1907 Schuster and Elderton (51) made a study of the inheritance of mental ability as indicated by the records of the classes at Oxford and in the Charterhouse and Harrow schools. They found a correlation of fathers and sons (as indicated by academic standing in the Oxford class lists) of .312, and a similar correla-

tion for brothers of .405. They conclude that these correlations are lower than those found by Pearson for physical measurements partly because the examinations for the B.A. degree at Oxford were less exact than the physical measurements. Various social selective factors also tend to lower the correlations. In the case of the Harrow and Charterhouse school records, the correlations fluctuated considerably, and the mean value was .398 for siblings. There were no parent-child correlations. In an appendix Pearson showed that the correlations obtained from the Oxford records based on a select group were probably equivalent to a correlation of from .44 to .54 for fathers and sons, and of .50 to .60 for siblings, if the correlations had been based upon a random selection from the general population.

A study by Miss Elderton (10) in 1909 indicated that the correlation of specific environmental traits with abilities or physical traits of children are usually under .10. Most of these correlations, such as that between employment of mothers and weight of sons, which was .12, are complicated because they depend in part upon underlying hereditary causes. Even so, they are very low as compared with the coefficients of familial resemblance.

In a paper published in 1910, Pearson (39) compared the results of the study of Oxford class lists with some data of his own. He had estimated that the most probable true correlation represented by the Oxford study was .49 for fathers and sons. His own data, based on a large number of family records, yielded a correla-

tion of fathers and sons in intelligence amounting to .58. These correlations do not differ appreciably from those obtained with a large number of physical measurements. He cites the correlations of siblings in several mental traits, ability, temperament, and handwriting, getting a mean value of about .52. The mean of a large number of parent-child correlations was .49, and of a large number of fraternal correlations, .52, giving a mean "nature" value of .51. From a long table of correlations of environmental conditions with the various traits measured, he obtained a mean "nurture" value of .03. These figures carry a suggestion of considerable force.

Since grades in school are to some extent an indication of mental ability, a few studies of family similarities in school grades will be reviewed. Starch (53), in 1915, studied the scholastic records of a number of families in several elementary school systems. An index of scholastic ability was obtained for each student, based on all studies pursued for one year. The following sibling correlations were obtained:

	n	*Rho*
First and second child in a family	63	.58
Second and third child in a family	24	.64
First and third child in a family	24	.34
Mean of the correlations		.52

For ability in special studies, sibling correlations were as follows, based on records from two schools in Madison:

	n	*Rho*
Spelling	57	.21
Reading	57	.49
Writing (speed)	24	.18
Writing (quality)	24	.06

Records from a Seattle school yielded these correlations:

	n	*Rho*
Arithmetic	54	.32
Spelling	54	.21
Reading	54	.31
Language	54	.24

The author concluded that abilities in special subjects are inherited to no greater extent in one subject than in another, and that general scholarship, or else traits more specialized than abilities in these studies, are inherited.

Miss Dexter, in 1915, studied sibling resemblances based on scholarship records in the University of Wisconsin, and in a Wisconsin high school. For a group of 185 in the University, she found a correlation of .69 in general scholastic ability, and an average correlation of .61 for ability in separate subjects, English, language, mathematics, history, and science. For the high-school group of 69 subjects, the correlation was .64 in general scholarship in all subjects, and, on the average, approximately .61 in three special subjects. Other correlations of interest are:

	General scholastic ability			
	High school		University	
	n	r	n	r
Brother-brother	10	.38	44	.47
Sister-sister	26	.39	71	.53
Brother-sister	23	.36	66	.62

She concluded that inheritance is primarily responsible for the degree of resemblance found, as the correlations are not higher for like-sex pairs than for unlike-sex pairs, as we should expect them to be if similarity of environment were an important factor.

In 1917 Starch (54) studied the correlations between siblings in two types of tests. For those tests of mental functions directly affected by school work the correlations between siblings were as indicated below:

Reading, speed	.51	Handwriting, speed	.72
Reading, comprehension	.64	Handwriting, quality	.46
Size of reading vocabulary	.07	Spelling ability	.05
Fundamentals of arithmetic, attempts			.49 (average)
Fundamentals of arithmetic, rights			.385 (average)

For functions not directly affected by school work, the correlations were:

Cancellation of A's	.50
Cancellation of geometric forms	.07
Memory for nouns, monosyllables	.31
Tapping (motor control)	.65

The subjects were adult siblings, ages 19 to 32, at the University of Wisconsin. The correlations in the case of tests directly affected by school work averaged .42, and in those traits not directly affected by school work, .38. He concluded that heredity, not training, causes the resemblances found among siblings.

In 1917 Cobb (8) published the results of a preliminary study of the inheritance of arithmetic ability. Her correlations were based on only eight families, with a total of 16 parents and 20 children, hence only the general trend of results is of significance. The main results were as follows:

	Correlation of child's score with score of		
	Mid-parent	Like-parent	Unlike-parent
Absolute ability	.32	.54	.08
Relative ability	.49	.60	.13

She was mainly concerned with the relative abilities in the different operations, and she discovered that if a child were better (for example) in addition than in subtraction, as measured by deviation from the mean for each, the same was likely to be true of one of the parents. It was not necessarily the same parent for all children in a family, and it might be either the like-sex or unlike-sex parent. Her conclusion was that abilities in the different functions seem to be inherited independently, one parent contributing more than the other.

In 1918 Pintner (42) tested a large number of grade children in two schools with a number of mental tests. Among these children were quite a large number of siblings. Getting a mental index for each child, based on all tests, he obtained measurements of resemblance of siblings as follows, using Yule's Coefficient of Association, Q:

	n	Q
School A	91	.47
School B	89	.28
Both schools	180	.39

Two chance selections of unrelated children gave coefficients of association of .14 and .19, respectively. The Pearson product-moment correlation for the 180 pairs of siblings was .22 with a probable error of .02.

In 1919 Dr. Kate Gordon (19) published the results of Stanford-Binet tests of 335 children in California orphanages. Where there were four siblings in a family group, she paired the first with the second, and the third with the fourth. Where there were three in a family, she omitted the youngest. The correlation between 91 pairs of siblings was .53. Karl Pearson re-worked the data, rendering the correlation table symmetrical, and obtained a correlation of .51, which agrees very well. He noted that, since the environment was very uniform for the members of different families, these correlations cannot be explained as due to environmental conditions. His own data on 2801 pairs of siblings yielded a correlation of .5147 and of .5158, calculating a correction for broad categories by two methods. In his case the intelligence measures were based on ratings on a six-point scale, and there was a widely varying environment. The agreement between these two sets of data, obtained under very different conditions, and by very different methods, is certainly striking.

The further work of Gordon was summarized by Miss Elderton (11). It gives the results of studies

of 216 pairs of siblings, using the Stanford Revision of the Binet Scale. She found widely different results in different orphanages, but for 216 pairs of siblings the correlation was .61. Miss Gordon used the same method of pairing as before. Pearson calculated the correlation for all possible pairs, and obtained a correlation of .467 with a probable error of .026 which is nearer the values usually found for sibling resemblances. Pearson found the data complicated by the factor of age, which was not eliminated by using IQ's. Using Dr. Gordon's method of pairing, and correcting for age, gave a correlation of .578. With all possible pairs of siblings, correction for age gave a correlation of .544. Using all possible pairs, and rendering the tables symmetrical gave a correlation of .53. The study of Gordon's data showed that siblings in orphanages where the environment is homogeneous resemble one another about as much as children whose home conditions vary more.

Miss Elderton also reviewed Drinkwater's data. The children in two school systems were tested, in most cases by use of the Stanford Revision of the Binet Scale. In addition to this, teachers' estimates of intelligence were obtained. The correlations of siblings in intelligence obtained in the first school, which was very superior, averaged .39 for IQ's and .59 for teachers' estimates, uncorrected for age. The corresponding figures for the second school, which was very inferior, were .43 and .43, respectively. Correction for age had little effect on the correlations. When the data for the two schools were combined, and the

correction made for the age factor, the average sibling correlations were approximately .47 for IQ's and .51 for teachers' estimates.

Hart (24) published in 1924 the results of some studies by the Iowa Child Welfare Research Station. Using three different groups, he obtained these correlations for siblings, based on intelligence quotients:

	r	*P.E.*
252 pairs, representative of public school children	.447	.034
147 pairs, representative of rural communities	.459	.066
219 pairs, highly selected (University of Iowa Schools)	.399	.057

He noted that, although there may be wide differences within a family in some cases, there is a tendency for mental ability to run in families.

In 1924 Madsen (32) published the results of application of the Stanford Revision to 880 school children. The reliability of the test was .85, with a probable error of .032, for 34 cases. In the total group were 63 pairs of siblings, and the sibling correlation was .63, with a probable error of .05. He found a corresponding correlation of —.04 between 63 pairs of unrelated children.

Merriman (33), in his study of twins, reported the unpublished data of Rensch on the intelligence of siblings as a comparison with his data on twins. For two different school systems, she obtained correlations between siblings which were on the average approximately .54 for intelligence quotients.

In 1925 Hildreth published the results of her study of intellectual resemblances of siblings. She had three

groups, the Oklahoma group being a random sampling, the Horace Mann group being of superior intelligence and economic class, and the Hebrew Orphans group being of average intelligence but of low economic and social class. Following are the results:

Group	r	Partial r, with age constant	Number of pairs	r, taking one pair in each family	Number of such pairs
Oklahoma	.63	.47	450	.64	300
Horace Mann	.27	.08	325	.26	241
Hebrew Orphans	.32	.13	253	.41	146
Composite	.68	.42	1028	.68	687

The average of her raw correlations, taking all pairs, is .41, and taking one pair from each family, .44. Probably the composite group gives correlations which are too high due to inclusion of extreme groups, and the raw correlations are too low in the second two groups due to selection. The raw correlations are, however, raised by the influence of age. We can probably place the greatest emphasis on the corrected correlation for the Oklahoma group, where the effect of age has been eliminated, and the group is relatively unselected. This correlation is .47, and agrees very well with the results of previous investigators.

In 1926 C. H. Griffitts (22) reported the results of study of similarities of siblings in school grades. Correlations were based on modal grades (school marks reduced to a numerical index) of children in a large number of families. He reported these correlations:

	Number of families	r
First and second child	657	.384
First and third child	226	.279
Second and third child	226	.332
First and fourth child	89	.208
Second and fourth child	89	.293
Third and fourth child	89	.300
Mean correlation		.299

The corresponding correlations for a subgroup including only the sixty families in which there were four children averaged .263. For a subgroup composed of the 137 families having three children the mean was .476. The main results of interest here may be summarized in two statements: First, the results of his analysis showed that the correlations are higher for adjacent than non-adjacent pairs of siblings; secondly, we see that the correlations average lower than the general trend of sibling correlations. The first fact Griffitts considers is due to effects of different home situations within the family for older and for younger children; however, it is likely that other irrelevant factors affect the correlations also. Griffitts points out that the grades are higher in small families than in large ones, and considers this probably due largely to presence of large families where the stock is poorer. The mean correlation for siblings in three-child families is higher than the mean correlation for siblings in four-child families, the values being .476 and .263, respectively. The measures used in the study were probably very reliable, as they included school grades on a great many subjects covering a period of

three years. The results indicate that the correlations between siblings are affected by some factors other than the biological factor, which tend to lower the correlations when the group is not homogeneous as regards age, grade, and training. Diversity of experience tends to cause lower correlations between sibling pairs who are separated by one or two or more other children in order of birth.

In 1927 Huestis and Otto (27) published the results of a study of grades of one hundred pairs of siblings who were students in the University of Oregon. The correlations were based on a numerical index weighted by amount of work carried as well as by grades obtained, and the group was homogeneous, all being sophomores. The correlations were:

	n	r	P.E.
Sister-sister	38	.61	.07
Brother-brother	26	.74	.06
Brother-sister	36	.04	.11

Social factors, and the small number of cases, may account for the variation in the values obtained. The mean value is .46, which is very near the usual value for sibling correlations.

The study by Thorndike (59), published in 1928, is very important on account of several features. The tests were accurately scaled, the number of cases was very large, and the correlations were corrected for attenuation. Very careful analysis of the data led to the conclusion that the true correlation between siblings in intelligence, in this high-school group, was approximately .60.

Willoughby's (61, 62) study is one of the few which contain data on parents and offspring as well as on siblings. He used a battery of 11 tests, and obtained these correlations:

	Mean correlations	
	Fraternal	Parent-child
Including all tests	.42	.35
Verbal tests	.43	.39
Non-verbal tests	.41	.30

In addition, he gives the correlations between husbands and wives, the average of which is .38. It will be noticed that for some reason the correlations here are consistently lower than the general trend in recent studies.

The work of Jones (28) is especially important as it also gives correlations between parents and offspring, and marital couples, as well as between siblings. He tested about 2500 persons in a New England rural community, and in the group were 105 families with both parents and two or more children. The Army Alpha test was used for parents and children above ten years of age, and the Stanford Revision for the younger children. His correlations were as follows:

	n	r	P.E.
Average r, siblings	828	.49	.018
Average r, father and child	317	.508	.028
Average r, mother and child	317	.548	.026
Average r, husband and wife	105	.598	.042

These correlations are consistently higher than those reported by Willoughby. Note that the correlation of husbands and wives is unusually high.

Miss Burks (4-7) also published her data in the 1928 Yearbook, in which the above-mentioned studies by Thorndike, Willoughby, and Jones appeared. The main results of her study which are of interest here are summarized below:

CORRELATION OF CHILD'S IQ WITH A NUMBER OF MEASURES

	Foster r	group n	Control r	group n
Father's MA	.07	178	.45	100
Mother's MA	.19	204	.46	105
Mid-parent MA	.20	174	.52	100
Father's vocabulary	.13	181	.47	101
Mother's vocabulary	.23	202	.43	104
Grade reached by father	.01	173	.27	102
Grade reached by mother	.17	194	.27	103
Corrected correlations:				
Father's MA	.09	178	.55	100
Mother's MA	.23	204	.57	105
Father's vocabulary	.14	181	.52	101
Mother's vocabulary	.25	202	.48	104

On page 289 Miss Burks gives the correlations of parents' vocabulary with child's vocabulary separately by ages. Since the numbers of cases are small, only the weighted averages will be given here:

MEAN OF CORRELATIONS

	n	raw	corrected
Foster group:			
Father-child	72	.28	.30
Mother-child	85	.34	.35
Control group:			
Father-child	42	.51	.54
Mother-child	41	.12	.13

It is evident from study of all the data obtained in this investigation that the influence of environment on the resemblances of related persons is far less than the influence of heredity.

The study by Freeman, Holzinger, and Mitchell (15), working with foster children in Chicago, contains the following correlations which are of interest to us here:

CORRELATIONS OBTAINED IN THE CHICAGO STUDY

	n	r	*P.E.*
Mid-parent's intelligence and child's IQ	28	.35	.11
Siblings reared apart, intelligence	125	.34	.05
Same, siblings reared apart, Negroes and those outside range 5-14 years eliminated	63	.44	.07
Correlation of child's IQ with:			
Otis score of foster father	180	.37	.04
Otis score of foster mother	255	.28	.04
Otis score of mid-foster parent	169	.39	.04
Otis score of mid-foster parent, Negroes and children outside 5-12 eliminated	112	.47	.05
Mid-foster parent, those placed under 2 years	132	.39	.05
Same, Negroes and children outside 5-14 years eliminated	104	.50	.05

It is evident that the correlations of foster parents and children are considerably higher here than in the Stanford study. This is perhaps due largely to the influence of selective placement. Our concern here, however, is mainly with the correlations obtained in the case of true parent and child. It is to be noted that these are considerably lower than in the majority of the investigations reviewed.

The two studies mentioned above did not show the

same trends as regards the cause of the correlations obtained. The results of the Stanford study lead to the conclusion that environment is a factor having little influence on the resemblances of parents and children. Miss Burk's comparison of the two studies indicates that the factor of selective placement which was operative in the case of the Chicago study may account largely for the differences in results. Freeman does not believe selective placement was operative to any great extent. Terman thinks it sufficient to explain several of the most striking differences in results obtained in the two studies. The impartial reader will wish to read the original articles to form his own opinion on the matter.

H. J. Banker (1) published in 1928 a study of correlations of related persons, based on school records. He happened to find a school in which the administration was very uniform over a long period of time, in a community with a population so stable that records of parents and children could be obtained. He reduced the school marks to a Students' Ability Index, which he considers equivalent to an IQ in significance. In this school twelve years of education were given, so that the records are based on several years' work. Records of 38 families were obtained which were satisfactory, giving marks for both parents and one or more children. A total of 83 children was included, and the correlations are as follows:

	n	r	$P.E.$
Child and mid-parent	83	.4999	.0555
Mid-parent and non-children	83	−.1172	.0730

Further study, utilizing all available data, yielded an average parent-child correlation of .46 and an average fraternal correlation of .45. The coefficient of assortative mating (homogamy) based on 45 pairs was .24 with a probable error of .095. These results agree very well with previous studies of inheritance of mental and physical characters in man.

The results discussed in the preceding pages make it clear that there is a large body of data supporting the inheritance of mental characters in man. It is evident that in interpreting the coefficients of resemblance for related pairs we must consider not only the size of the coefficients obtained, but the conditions under which the basic data were secured, and the characteristics of the group. Widely varying results are obtained under extreme conditions, but the general trend is clearly marked. A selected group of subjects yields lower correlations. In general, the correlations of parents and offspring and those of siblings should be about the same and approximately .50 for a random group. Frequently the correlations of siblings are slightly larger than those of parents and offspring. The work of Jones (28) indicates that the factor of assortative mating (homogamy) must be given close attention in connection with studies of inheritance by the biometric method.

Marital Resemblances

The investigation of the resemblance between husbands and wives by scientific men began before the turn of the century, and the subject has been studied with increasing interest since. The earliest studies

were, of course, limited by the lack of development of statistical methods and by the lack of adequate measuring instruments.

In 1891 Fol (14) published the results of a study of the resemblance between husbands and wives. He used photographs, and the study was carried out as carefully as possible, but of course the method was not objective or quantitative. He arrived at the conclusion that like people marry, not unlike, and that the oft-noted resemblance between aged couples is not due to their life together, but exists from the time of marriage because of selection.

In 1900 Karl Pearson published, in the second edition of his *Grammar of Science,* the results of correlations of husbands and wives in two physical traits. In stature the result was a correlation of .2872 for 1000 pairs, and in eye-color a correlation of .1002 for 774 cases. He concluded that the resemblance is very striking, noting that in the case of stature it is greater than the resemblance of uncle and niece, and in eye-color is greater than that of first cousins.

From a study of Pearson's family records, Pearson and Lee (37) found the correlations of husbands and wives in physical traits to be as follows: stature, .28; span, .1989; length of forearm, .1977; the average of the three is .2257. This resemblance is greater than that of great-grandparents to their great-grandchildren, which, as Pearson noted, is about .20. He had previously found from study of Galton's records of 200 families that the correlation for stature was .09 with a probable error of .05, but when limited to those cases

having adult offspring it was .18 with a probable error of .02, which agreed well with the present results. This he concluded may be due to reproductive selection, a correlation between homogamy (tendency for like to mate with like) and fertility.

A cooperative study published in 1903 showed the relation between husbands and wives in duration of life. The results were as follows:

Source of data	r	P.E.
Wensleydale and district	.2200	.0244
Oxfordshire	.2500	.0211
Society of Friends	.1999	.0202
Mean correlation	.2233	

This shows very close agreement with Pearson's results with physical characters. Duration of life was shown, in an earlier study, to be inherited. It may be regarded as a rough indication of general physical fitness, and hence the correlations above may be regarded as measures of the tendency for like to mate with like. The results of similar study of London Cemetery material gave a correlation of .4204 with a probable error of .0176, which was considered spuriously high, because of the transitoriness of the population, which would prevent burial of husband and wife in the same grave if they died many years apart.

Franz Boas (2) published in 1903 the results of study of records of 48 Jewish families, the records being collected by Dr. Maurice Fishberg. The trait studied was cephalic index, and the correlation between husbands and wives was .15.

Lutz (31) (1905) compared the correlations of husbands and wives in a trait where there certainly is conscious selection, with the results of the studies cited above. He tabulated the ages of 2500 married couples as given at the marriage license office at Chicago during the spring of 1904, and found a coefficient of assortative mating of .764. This is considerably higher, partly due, perhaps, to the tendency for possible falsification of ages to raise the correlation, but mainly because of the conscious selection of mates of similar ages.

In 1908 Schuster and Elderton (52) published the results of a statistical analysis of the data collected by Heymans and Wiersma, which was previously not handled quantitatively. The coefficients of assortative mating ranged from .73 for "religious feeling" to −.28 for "anxious or sanguine." Not much emphasis can be placed on this data because of the method of collection. Forms were sent to 3000 Dutch physicians, asking each one to answer ninety searching questions about one family. As Pearson states, these doctors would not often be able to answer the questions accurately for any family but their own, and it is likely that the doctors did use their own families in many cases. This would often lead to placing the two parents in opposite categories, and rating the children as like one or the other; such subjective rating schemes would vary from case to case, and would help to explain the negative correlations of husbands and wives. The negative correlations are evidently present in the case of those traits most difficult to judge, which would serve to support Pearson's conclusions.

Schuster (50) (1906) applied statistical methods to the treatment of the data on deaf couples collected by Dr. E. A. Fay in America. Records of 4471 pairs were available, but, due to some complications in the data, the coefficient of assortative mating could not be determined exactly, although he stated that it is certainly above .90. There is a pronounced tendency for deaf persons to marry deaf persons, which anyone can readily understand.

Karl Pearson and Miss Elderton (1908) published results on the data of Pope concerning the statistics of pulmonary tuberculosis, and concerning assortative mating in man. A rather extensive table appears on page 22 of the memoir, summarizing the studies of assortative mating in man which had appeared at that time. The results presented are shown in the table on the following page, and they include much of that summarized in the preceding pages here. The mean marital correlation for a number of physical traits was .24 and for a number of psychical traits .24. Some of the results on physical traits, and all of those on psychical traits, were values derived from contingency coefficients. For the trait of insanity, a correlation of .30 was presented, a value obtained by Miss Elderton from study of Pearson's family records, using the method of four-fold tables.

For Pope's own data proper, the coefficient of resemblance of husbands and wives in tuberculosis was .17. When corrected for sampling, Pearson found a correlation of .32. This was in good agreement with results from the best previous series of data on the subject.

DATA ON ASSORTATIVE MATING IN MAN, FROM THE TABLE ON PAGE 22 OF THE MEMOIR WHICH INCLUDED PEARSON'S AND ELDERTON'S ANALYSIS OF POPE'S DATA

Character	Correlation	Method	*Authority*	Remarks
Eye-color	.26	C.	Pearson	Galton's data.
Stature	.28	r.	Pearson & Lee	
Span	.20	r.	" "	Pearson's family measurements.
Forearm	.20	r.	" "	
Length of life				
a. Yorkshire	.20	r.	Weldon & Pearson	Data collected by Fawcett, Beeton, Weldon, and Pearson.
b. Oxfordshire	.25	r.	" "	
c. Society of Friends	.20	r.	" "	
Alcoholism	.27	C.	Schuster & Elderton	Heymans' and Wiersma's data.
General health	.27	C.	E. M. Elderton	Pearson's family records.
Mean, physical traits	.24			
Intelligence	.33	C.	E. M. Elderton	Pearson's family records.
Truthfulness	.22	C.	Schuster & Elderton	Heymans' and Wiersma's data.
Temper	.18	C.	E. M. Elderton	Pearson's family records.
Temperament, excitable	.11	C.	"	" " "
Temperament, reserved	.27	C.	"	" " "
Temperament, sympathetic	.15	C.	"	" " "
Success in career	.48	C.	"	
Neglect of duty	.20	C.	Schuster & Elderton	Heymans' and Wiersma's data.
Tone of voice	.26	C.	" "	
Mean, psychical traits	.24			
Insanity	.30	Four-fold tables	E. M. Elderton	Pearson's family records.

Goring (21) (1909) found a correlation between husbands and wives in the "tubercular diathesis" of —.0072. The data were based on a study of family histories of 1500 criminals. He also gives the following table of correlations, calculated by the method of four-fold tables:

Character	Class of population	Number of couples	Correl. coeff.
Pulmonary T. B.	All	723	—.01
"	Well to do and prosperous poor	462	.16
"	Very poor and destitute	261	
Insanity	All	1433	.06
"	Well to do and prosperous poor	493	.35
"	Very poor and destitute	257	
Criminality	All	474	.20
"	Well to do and prosperous poor		
"	Very poor and destitute	153	.18
Alcoholism	All	1426	.70
"	Well to do	65	.69
"	Prosperous poor	244	.58
"	Very poor and destitute	151	.44
Freedom from constitutional disease	All	437	.11
	Well to do and prosperous poor	296	.08
	Very poor and destitute	141	.17
Either phthisis or insanity	All	485	—.01

Goring calls our attention to the fact that the marital coefficients get larger as we pass upwards on the social scale; this leads him to believe that the higher values obtained by other investigators represent assortative mating for the most part, and infection only to a small degree. In insanity, where infection is ruled out, the correlation is twice as great as for tuberculosis. For the last entry in the table, where husband and wife are both diseased, one having phthisis, the other insanity,

the correlation is —.01. In this case assortative mating and infection are both ruled out, and the coefficient represents no correlation at all.

From a study of Galton's early records, Harris (23) (1912) obtained a coefficient of mean square contingency between husbands and wives in hair color of .34. He presents in the same paper a valuable summary of previous literature on the subject. The results of Woods' study, which we have not yet discussed in this connection, are among the many included. Woods found between intellectual grades of husbands and wives in 229 royal marriages a correlation of .08 with a probable error of .076. This is what we should expect, since others plan these marriages, and we should not expect to find much evidence of assortative mating.

Williams, Bell, and Pearson (60) (1914) found the correlation (tetrachoric) between husbands and wives in rheumatism to be .136. This they note cannot be due to environment, as the husband and wife are together much longer than parent and child, but the parent-child correlation is much higher, averaging .63. It is, of course, possible that one represents effects of environment alone, the other environment plus heredity. This, however, is very highly improbable, and it is most likely that the correlation between husbands and wives here found is due to assortative mating for traits associated with rheumatic constitution. Later results presented in the same paper show a mean parent-child correlation of .46.

Jones (29) (1929) reports a correlation of .10 with a probable error of .08 between 45 pairs of parents, in

regard to scores on the Pintner-Paterson performance test. The data studied were those of Moorees (34) (1924). This correlation determined by Jones is very low, and must be interpreted in the light of the fact that the people were all parents of children in an institution for the feebleminded. The narrow range partly accounts for the results, especially since coefficients of marital resemblance tend to be lower when the sample is taken from the lower classes of the population. Jones credits Moorees with the first objective measurements of mental test abilities in husbands and wives.

The results of the several articles in the 1928 *Yearbook of the National Society for the Study of Education*, which present data on this subject, will be summarized together. Willoughby presents the correlations between married pairs in regard to eleven psychological tests, with an average raw correlation of .38 and an average corrected coefficient of .44. The tests were very reliable, hence the correction for attenuation is small. The average corrected correlation for the five verbal tests was .44, and the average was the same for the six non-verbal tests.

Miss Burks reports coefficients of assortative mating, for mental ages on the Stanford Revision, as follows:

	r	*P.E.*	*n*
Foster group	.42	.04	174
Control group	.55	.05	100

These average slightly higher than Willoughby's corrected coefficients, but somewhat lower than the cor-

relation reported by Jones between husbands and wives in Army Alpha. Jones had 105 cases, and the correlation was .598 with a probable error of .042.

The Chicago study of foster children showed a correlation between husbands and wives, as measured by the Otis test, of .49. This agrees very well with Miss Burks's results. With type of home kept constant, this correlation was reduced to .22 but that is a factor which should not be kept constant if we are endeavoring to measure the extent of homogamy. Hence the correlation of .49 is the one to emphasize in this connection.

H. J. Banker (1) (1928) found a coefficient of assortative mating of .24 with a probable error of .095 for 45 pairs of husbands and wives. The correlation was based on a study of school grades reduced to a Student's Ability Index. This is lower than the general trend of recent studies, but the number of cases is small, and the group probably homogeneous.

The recent work of Jones (29) (1929) is especially valuable because of its complete and careful presentation of the facts of assortative mating, beginning with the earliest studies, and including all up to the present time. The reader will wish to examine in detail the carefully prepared tables presented therein, hence only a summary will be presented here. The early studies showed a correlation between husbands and wives in physical traits around .25; in mental traits, likewise, early studies found values fluctuating about this amount, roughly speaking. The more recent work, especially that published in the 1928 *Yearbook*, with

better tests and more adequate technique, shows the correlation in mental traits to be somewhere in the neighborhood of .50. Jones presents a discussion of various types of selective factors which contribute to this resemblance. One very important fact which he brings out is that any adequate discussion of inheritance must not merely take into account the correlations between parents and children and between siblings, but must interpret them in the light of the coefficients of marital resemblance. He discusses additional literature bearing on the general problem and indicates further implications depending on the social effects of the facts of marital resemblance. He cites the data of Willoughby in detail, and notes that higher coefficients are to be expected in the case of the Jones data because of wider selection and greater variability. He also mentions the fact that the higher correlations for the control group in the Burks study are in line with the belief that there is a positive relation between homogamy and fertility.

It is difficult to understand how it is possible for the belief that opposites attract to be seriously indulged in by many educated persons, in the face of all this evidence which has been accumulating for over 35 years. Such a belief, however, seems to be widely prevalent. The evidence points unmistakably to the fact that like tends to mate with like, where the traits under consideration are such as to be a factor in selection, and even in traits not directly considered but which are related to those facts upon which selection depends.

II

THE DESCRIPTION OF THE DATA

Tests and Procedure

The Courtis Standard Research Tests in Arithmetic, Series B, were used in this study. These consist of four subtests, one for each of the fundamental operations, as follows:

Addition	8 minutes	24 examples
Subtraction	4 minutes	24 examples
Multiplication	6 minutes	25 examples
Division	8 minutes	24 examples

These tests are all timed so that it is very unusual for anyone to complete the tests. Scoring was done according to number right.

Vocabulary Tests A and B of the University of Minnesota College Aptitude Tests were also used. Each test is three pages long, and the subject is given directions as follows:

> "After each word in capital letters there are five answers, only one of which defines it. Pick out the right answer and draw a line under it for reference. Then put the number of that answer in the parenthesis ( ) at the end of the line, as shown in the samples below. You will be given fifteen minutes to answer 120 items. If you do not know, guess. The first two samples are marked correctly."

The words were systematically selected from the eight-, nine-, and ten-thousand-word levels in the ten thousand most frequently used words according to Thorndike's running count of about 4,565,000 words

(See *The Teacher's Word Book.*) For college entrants, the examination is a power test, not a speed test. Most subjects have no difficulty in finishing, but no perfect scores were obtained.

The two vocabulary tests and two forms of the arithmetic tests were given to all the subjects. The testing was done by the writer, with the exception of three families. Wherever possible, whole families were tested at one sitting. Spaces were provided on the blanks for securing information as to age, sex, school grade reached, and the date of the examination. First one arithmetic test was administered, then both vocabulary tests, and then the other arithmetic test. The total testing time was 82 minutes of actual work, but the procedure usually took about two hours, as the subjects did not wish to work without rest periods. This was particularly true of the parents and the younger children, and it is likely that the work periods were well adjusted to the demands of the subjects.

The Subjects

One hundred and eight families were tested where both parents and one or more children over 12 years of age were available. In addition, records of two or more persons in each of 31 incomplete family groups were obtained in the course of the investigation. A dozen or so unrelated individuals also took the tests along with families with whom they were acquainted. Several groups of college students were given the tests, to determine reliability coefficients for such groups. In the complete-family group, with which we are

mainly concerned, there were 446 cases, composed of 216 parents and 230 children.

A first appeal was made to the psychology students who lived in the nearby urban community, and in this way some cases were obtained. From each family tested, a list of people who would be likely to co-operate was obtained, and this list steadily increased. Within this group the only selective factor operating was the willingness of the persons concerned. In general, it may be said that the group includes grade-school, high-school, and college students, and their parents; the younger children belong to the class who are likely to attend college in the future. There is no reason to suppose that the older children were any more highly selected than the younger ones, as there was no direct selection from the schools.

General Treatment of the Data

Each person's average score in the two vocabulary tests was obtained, and these averages used as the measure of the person's vocabulary. For the children, a curve was drawn showing the increase in score with age, and each individual's score was reduced to a sigma score by Formula I.

$$x = \left[\left(\frac{X - \bar{x}}{\sigma_x} \right) 10 \right] + 50. \qquad \text{Formula I}$$

In this formula, x is the sigma score, X is the raw score, $\bar{x}$ is the average for the age group represented, and σ_x is the standard deviation for the age group in which the individual happened to fall. For both

vocabulary and arithmetic an increase in ability could be seen to extend up through age twenty.

For each of the subtests in arithmetic a similar age curve was drawn, and the score for each person expressed in terms of deviation from the mean of the age group in which the person belonged. This deviation was divided by the standard deviation of the age group, and the result multiplied by ten, making the standard deviation of the resulting sigma scores approximately ten for all groups. Adding the constant, 50, made all scores positive, and the mean approximately 50 for all groups. This is, of course, the same procedure as was described above in the case of vocabulary by means of Formula I.

The present study deals only with general computation ability and vocabulary ability. The sigma scores of the separate arithmetic tests were averaged, and the resulting total arithmetic scores dealt with. Further treatment of the relative abilities within the field of computation is reserved for a later paper.

The average score for parents was determined separately for each sex, and each person's score expressed as a fraction of the standard deviation above or below the mean for that sex, and then the constant 50 added. This procedure may be described by use of Formula I also, where x is the average for parents of that sex, and σ_x is the standard deviation for parents of that sex. The total arithmetic score was obtained by averaging the sigma scores for the separate tests. The influence of age was evident in the scores of the fathers, and was eliminated by use of a procedure to be described later.

In determining the sigma scores the calculator was used, and each step carefully checked; the values were put in the form of typewritten tables as soon as obtained. The writer considers this method less laborious and far more accurate than the graphical method. The result of the process was to make the scores obtained by persons of different ages roughly comparable. This was necessary in order to compare the scores of parents with those of their offspring, and to compare the scores of siblings of different ages. On the basis of the scores thus obtained, the correlations between parents and offspring and between siblings were calculated.

Reliability Coefficients

The reliability coefficients of the tests were calculated from the raw scores. For the children these coefficients were calculated for separate age groups to avoid spurious correlation due to the age factor. The correlation was calculated for first subtest versus second, and the reliability of the total test determined by the Spearman-Brown formula. All correlations were calculated by the Pearson product-moment method, except those for children of the ages 10, 11, and 12. These were calculated by the rank-difference method, converted to r-values by formula, and the result used in getting the reliability of the total. The reliability coefficients for the total test are presented in Table 1.

The total arithmetic test, obtained by averaging the scores of the four subtests, has a reliability of .97 for the fathers, .96 for the mothers, and about .95 for col-

lege students or for children in homogeneous age groups. The reliability of the vocabulary test is .96 for the fathers, .96 for the mothers, and about .92 for college students or children in homogeneous age groups.

TABLE 1

RELIABILITY COEFFICIENTS

	Arithmetic		Vocabulary	
Age	n	r	n	r
A. For the Children				
10	13	.97	13	.94
11	14	.98	14	.96
12	13	.94	13	.90
13	21	.96	21	.92
14	35	.95	35	.92
15	31	.94	31	.89
16	31	.96	31	.93
17	26	.93	26	.93
18	27	.96	27	.94
19, 20	37	.97	37	.92
B. Reliability Coefficients for Parents				
	Arithmetic		Vocabulary	
	n	r	n	r
Fathers	108	.97	106	.96
Mothers	104	.96	116	.96

C. Reliability Coefficients for College Students

		r
Vocabulary	162 sophomores	.92
Arithmetic	20 "	.94
"	34 "	.97
"	44 "	.94
"	23 "	.95
"	39 juniors	.95

It will be noticed that the reliabilities of the arithmetic test average .95 or over for all groups concerned, and for the vocabulary test .92 or over. While not much emphasis is placed on the exact values, the results given furnish a good indication of the general trend, and it is safe to say that the tests differentiate well at all levels represented.

Correlations between the Two Tests

The correlations in Table 2 were calculated to determine for different groups the extent to which performance on the arithmetical computation test is correlated with performance on the vocabulary test.

TABLE 2

Correlation between Arithmetic and Vocabulary Tests

	n	r	P.E.
Fathers	108	.36	.056
Mothers	108	.46	.051
Sons	147	.22	.053
Daughters	157	.19	.052
Mean		.31	

We wish to know the extent to which these tests measure separate types of ability. The average of the correlations is about .31, but they vary considerably; the average of the correlations for the parents is .41, and for the children it is .205. The sigma scores were used in the calculation. In view of the high reliability coefficients of the tests, it may be said that each test is consistently measuring something not measured by the other.[1]

[1]There are several lines of evidence to indicate that computational ability is a special ability. In 1921 Buckingham (3) found a correlation between computation tests and general intelligence of .41 for a group of 350 pupils in grades seven and eight. He used the parts of the Illinois Intelligence Examination. This correlation is *evidently* much lower than the intercorrelations of either verbal tests or numerical tests. He concluded that ability in computation is largely a matter of practice, and is less influenced by intelligence than is ability in reasoning.

The work of Schneck (49) in 1929, using an entirely different technique, showed clearly the existence of a factor of numerical ability rather independent of verbal ability.

III. AGE, SEX, AND EDUCATIONAL DIFFERENCES

Sex Differences

In any study of possible inheritance of a trait, the factor of sex must be taken into consideration, both on account of biological factors associated with a difference in the sex chromosomes, and on account of social factors. Given equal endowment, it is to be expected that the two sexes will differ in some respects, due to traditional differences in training. Moreover, it is far from safe to assume equal endowment in every case a priori.

In the present study sex differences were found among the parents, and it is assumed that some of these are more likely due to differences in experience than to differences in native capacity, although both factors may have operated. The main differences are shown in Table 3.

TABLE 3
Scores of the Parents (Means and *S.D.*'s).

	Fathers			Mothers		
	n	Mean	*S.D.*	*n*	Mean	*S.D.*
Vocabulary	105	89.9	22.0	123	92.6	18.6
Arithmetic	108	13.2	4.6	123	8.6	4.4
Years of Educ.	99	13.6	3.9	99	13.0	2.6
Age	108	49.5	6.4	123	45.2	5.9

In vocabulary the women are slightly superior, but not significantly so. In arithmetic the men are decidedly superior to their wives, the difference being very significant. Table 4 will aid in interpreting their findings:

TABLE 4

	Sex difference	S.D. diff.	Diff. / S.D. diff.
Vocabulary	2.7	2.7	1.0
Arithmetic	4.6	.59	7.74
Years of educ.	.6	.47	1.27
Age	4.3	.81	5.28

The men have, on the average, half a year more education than their wives, and they are 4.3 years older. The men are the more variable (absolute) in all the measures shown, although in arithmetic the women are relatively more variable, as shown by the coefficient of variability (standard deviation divided by the mean) of 34.6% for the men and 50.6% for the women. The only significant sex differences are in arithmetic ability and age, the first being due, probably, to practice. Since the sigma scores were obtained separately for men and women, these differences in arithmetic and vocabulary have been eliminated from the scores of the parents before proceeding with the computations involved in the main part of the study. Another important sex difference will be discussed in the section dealing with the influence of age on the performances of adults.

Sex Differences among the Children

Boys and girls in the same family in this community probably have approximately equal educational opportunities at the present time, and hence if sex differences are found they may really indicate differences in capacity. However, it is likely that more obscure fac-

tors than formal training are operative in producing them, and it is probable that traditional cultural influences have a part in causing them.

To be sure that we are dealing with sex differences and not age differences, it has been necessary to consider the age groups separately. The subdivisions have not been carried farther, due to the small numbers of cases at each age level. Table 5 shows the results which have been discovered.

The differences are certainly small, inconsistent, and statistically insignificant. It is possible that a larger number of cases would indicate a slight difference in favor of the girls, as the larger differences are in their

TABLE 5

Age group	*n*	Mean	*S.D.*	*S.D.* / *M*
		Boys' Scores in Vocabulary		
10, 11, 12	24	48.83	19.93	4.07
13, 14	30	77.	17.4	3.18
15, 16	27	89.67	13.73	2.64
17, 18	19	92.89	14.06	3.22
19, 20	15	98.73	13.66	3.53
21-30	32	99.38	13.17	2.33
		Girls' Scores in Vocabulary		
10, 11, 12	16	59.75	24.3	6.07
13, 14	26	77.	14.43	2.83
15, 16	35	87.68	10.50	1.77
17, 18	34	100.06	10.33	1.77
19, 20	22	99.54	10.04	2.14
21-30	24	99.17	15.21	3.10

Sex Differences in Vocabulary

	Favoring girls	Favoring boys	*S.D.* *diff.*	*Diff.* / *S.D.* *diff.*
10, 11, 12	10.92		7.31	1.49
13, 14	0.0	0.0	4.26	0.0
15, 16		1.99	3.18	.62
17, 18	7.17		3.67	1.95
19, 20	.81		4.13	.20
21-30		.21	3.88	.05

favor. However, none of the differences here found is statistically significant, and while three favor the girls, two favor the boys, and in one age group there is no difference. There is nothing in these data to justify computing separate averages for boys and girls in determining the sigma scores.

Table 6 presents the results of similar treatment of the data with regard to arithmetic scores.

TABLE 6

Age group	*n*	Mean	*S.D.*	*S.D.* / *M*
		Boys' Scores in Arithmetic		
10, 11, 12	24	6.08	3.07	.63
13, 14	30	8.80	3.98	.73
15, 16	27	8.28	3.10	.60
17, 18	19	9.92	3.70	.85
19, 20	15	11.7	3.27	.84
21-30	32	12.78	3.94	.70
		Girls' Scores in Arithmetic		
10, 11, 12	16	6.81	3.01	.75
13, 14	26	9.88	3.12	.65
15, 16	35	9.73	3.56	.60
17, 18	34	10.70	3.76	.64
19, 20	22	12.50	4.81	1.03
21-30	24	10.42	3.83	.78
		Sex Differences in Arithmetic		
	Favoring girls	Favoring boys	*S.D.* *diff.*	*Diff.* / *S.D.* *diff.*
10, 11, 12	.73		.98	.74
13, 14	1.08		.98	1.11
15, 16	1.45		.85	1.71
17, 18	.78		1.07	.73
19, 20	.80		1.33	.60
21-30		2.36	1.05	2.26

Differences in arithmetic favor the girls. However, none of the differences is significant, and for the oldest group, where the difference is largest, it actually favors the boys. With a larger body of data we should

probably find girls superior at all ages up to maturity, and the lines would probably cross somewhere around age twenty. This suggests that, after leaving school and entering non-academic life, the work of men causes continued practice in arithmetic more than does the work of women. The difference here for ages 21 to 30 indicates that the superiority of adult males is present in early maturity as well as at later stages in life. The superiority of girls at younger ages may be due in part to greater studiousness, and in part to earlier maturity. These differences are not statistically significant, and do not justify calculation of norms separately for the sexes.

For both vocabulary and arithmetic the differences we have found are typical of sex differences in general in such tests. They are usually found to be small and unimportant as compared with individual differences.

To avoid unnecessary errors of sampling, the boys and girls were grouped together to determine the age averages used in getting the sigma scores. Thus, in the case of the children, the process of getting sigma scores has eliminated only the age factor, and has not eliminated these small sex differences. All calculations of family resemblances have been carried out separately by sexes, so that similarities of persons of like sex due either to original nature or to training may show themselves in the correlations.

Educational Differences

The differences in the case of the parents have been mentioned above in the section on sex differences.

TABLE 7

THE EFFECT OF THE PARENTS' EDUCATION

	n	n'	r	*Min. P.E.	Max. P.E.
Correlation of Years Educ. of Father with:					
Father's arith. score	99	99	—.05	.07	.07
Son's arith. score	102	74	.11	.065	.08
Daughter's arith. score	107	79	.02	.065	.08
Father's vocab. score	99	99	.51	.05	.05
Son's vocab. score	101	74	.05	.07	.08
Daughter's vocab. score	107	79	.15	.06	.07
Correlation of Years Educ. of Mother with:					
Mother's arith. score	99	99	.28	.06	.06
Son's arith. score	102	74	.01	.07	.08
Daughter's arith. score	107	79	.11	.06	.08
Mother's vocab. score	99	99	.49	.05	.05
Son's vocab. score	101	74	—.02	.07	.08
Daughter's vocab. score	107	79	.06	.065	.08

*The value labelled Minimum *P.E.* means the value of the probable error taking the total number of pairs as the number of cases. The value labelled Maximum *P.E.* means the value of the probable error taking the number of cases as the number of pairs possible without using any individual's score in more than one pair. The true value of the probable error of the obtained correlation lies between the two. The letter *n* is used to designate the number of pairs used in calculating the correlation (total number); the letter *n'* is used to designate the number of pairs possible *without using any individual in more than one pair.* This notation is used throughout this manuscript.

However, some additional facts of importance are revealed by the correlations in Table 7.

In the case of arithmetic, the correlations are all surprisingly low. The father's standing in arithmetical computation tests seems to be practically independent of the amount of his formal education. In the case of the mothers, however, there is a noticeably positive correlation. Altogether, it may be said that the ability of the parents in the arithmetic test seems to be very slightly correlated with amount of education as measured by the number of years in school (average

correlation .115), but it is well to keep in mind the fact that there is a significant difference between the correlations found for men and for women in this respect.

There is a marked correlation (average is .51) between amount of formal education and vocabulary score for these parents. This may be due in part to dependence of both on some third factor, such as biological heredity.

It may be seen from inspection of both tables that there is a very slight positive correlation between years of education of the parent and score of the child on these tests. This cannot be caused directly by the training the parent received, but may be due either to association of parent and child, or to an inherited similarity in general level of ability, which affects the scores, or to both. Most of these correlations are not larger than their probable errors, but, of the eight, seven are positive and only one is negative. In general, these correlations are smaller than has usually been found. The significance of this fact will be discussed in a later section of this monograph.

Children's Education

In the case of the children, correlations of their scores with educational status are more difficult to interpret and evaluate. Since the factor of age is responsible for a part of the correlation, and since the age factor has been eliminated from the sigma scores, a comparison of the correlations of grade with raw score and with sigma score may reveal something concerning the effects of schooling. However, the factor of in-

telligence has a bearing on educational status, as well as on the scores in the tests, for these younger people especially, and this must be taken into account. Because of this, it has not been considered permissible to eliminate the factor of education. An exhaustive study of this factor, although desirable, is outside the scope of this thesis. Those correlations which have been calculated are presented in Table 8.

It is, of course, to be expected that the sigma scores (age factor eliminated) should still correlate somewhat with grade in school, since both would depend upon underlying scholastic ability to some extent. It is evident, nevertheless, that most of the relation between school grade and test ability is eliminated when the effects of age are ruled out. Although computation ability is ordinarily considered to be much affected by training, there is very little correlation between test performance and school grade when the factor of age is ruled out, and the correlation is lower than in the case of vocabulary. For both types of

TABLE 8

	Vocabulary			Arithmetic		
	n	r	P.E.	n	r	P.E.
Grade and raw score						
Boys	143	.73	.026	143	.58	.037
Girls	151	.73	.026	151	.35	.048
Average		.73			.465	
Grade and sigma score						
Boys	143	.23	.054	143	.22	.054
Girls	151	.20	.053	151	.01	.055
Average		.215			.115	

Correlation of age and grade

	n	r	P.E.
Boys	143	.86	.015
Girls	151	.86	.014

performance, the correlation of age with raw score (see later section) is just slightly lower than the correlation of grade with raw score (difference not significant). The correlation of age and grade is .86, but might be higher if the 35 cases in the age group from 22 to 30 had been eliminated.

The Age Factor (Adults)

The ages of the fathers in the group range from 37 to 66 years, with an average of 49.53 and a standard deviation of 6.36. The mothers' ages range from 31 to to 62, with an average of 45.19 and a standard deviation of 5.94. It is evident from this wide range that the factor of age must be considered carefully, as it might conceivably have some bearing on the ability of the subjects. The correlations are presented in Table 9.

TABLE 9

The Effects of Age on Adult Performance

	n	*r*	*P.E.*
Men:			
Age and arith. score	108	—.25	.06
Age and vocabe scor.	108	—.24	.06
Age and years of educ.	99	—.17	.065
Women:			
Age and arith. score	123	.09	.06
Age and vocab. score	123	—.01	.06
Age and years of educ.	99	—.16	.07

The correlations are negative in the case of the men, but practically zero for the women. No marked relationship is indicated, but we are justified in saying that there is a slight tendency for the men to show a decrease in ability on these tests as they get older. The decrease is slight, but present to practically the same

extent in both types of performance. It may be due to later maturity, or to selective factors of some sort.

The slightly greater age of the men cannot account for the sex difference in the decline. In the first place, inspection of the correlation plots did not reveal a curvilinear relationship. Secondly, there is no law of development which would lead us to expect a sudden decline rather than a gradual decline over a period of years. In the third place, there is tremendous overlapping in the age ranges of the men and the women.

The apparent decline may be due to some sort of selection; the older men are less able, but they may have been less able when young, and age may have nothing to do with it. The negative correlation between age and years of education is perhaps sufficient to account for some of the decrease in ability with age. However, as years of education is a factor related to aptitude, the elimination of that factor by the partial correlation technique would not give results easily interpreted. We see that this negative correlation of years of education with age is present for both sexes, which may mean that it does not help to explain the decrease in ability with age, which occurred only in the case of the men. We cannot be sure of this, as educational opportunities were not always the same for the two sexes, and it is perfectly possible that the older women are relatively more highly selected, so that a later maturity decline is concealed.

It seems reasonable to accept the conclusion that we have here a true decline in ability with increasing age, on the part of the men. Accordingly, the correlations

of fathers' scores with children's scores (see Section IV) were calculated both before and after the effects of age were eliminated from the scores of the fathers.

The equations for the regression of arithmetic and vocabulary on age for the fathers were

$$x = -.1797\ z$$
$$y = -.825\ \ z$$

where x is the arithmetic score, y is the vocabulary score, and z is the age, all expressed as deviations from the means. By means of these equations, the most probable deficits due to age were calculated. Each man's score was then corrected: if he were older than average, a small amount was to be added; if he were younger, a small amount was to be subtracted. The correction in raw score is larger for vocabulary, because of the greater mean and standard deviation of the vocabulary scores. The corrections in sigma scores are about the same for both, as the correlations with age (given above) were very nearly the same.

After correcting the scores of the fathers by this method, the correlation of those scores with age were .05 and .00 for arithmetic and vocabulary, respectively. The number of cases is 108 and the probable error is .06 for each of these correlations. This indicates that this method of eliminating the age effect was satisfactory.

The effects of age were eliminated from the children's scores in a different way (see Formula I, Section II), because the curvilinearity of regression of scores on age for the younger group made this method unsatisfactory. The sigma score technique which was

used in the case of the children is less satisfactory here because of the smaller number of cases and the greater age range of the fathers.

AGE FACTOR (CHILDREN)

Since the children in these families range in age from 10 to 30, and since age is known to be of considerable importance in ability at the younger ages, we expect in advance to find some interesting and important age effects in the case of the children. Because the line of means for scores by ages was known to be curvilinear, the correlation ratio was used, as well as the Pearson product-moment coefficient, as a measure

TABLE 10

EFFECTS OF AGE ON CHILDREN'S PERFORMANCE

Correlation of age with:	n	r	P.E.	Corrected Eta	P.E. eta
Vocab. raw score					
Boys	147	.62	.034	.73	.025
Girls	157	.59	.035	.65	.031
Average		.605		.69	
Arithmetic raw score					
Boys	147	.47	.043	.53	.040
Girls	157	.23	.051	.36	.047
Average		.35		.445	

RESULTS OF BLAKEMAN'S TEST FOR LINEARITY OF REGRESSION

Correlation:	Zeta	P.E. Zeta	Zeta / P.E. zeta	Chances in 100 the relation is curvilinear
Age and vocab.				
Boys	.1547	.0438	3.53	99.
Girls	.1143	.0364	.314	98.
Age and arith.				
Boys	.0645	.0268	2.40	94.
Girls	.0740	.0293	2.54	95.

of the relationship. The results are presented in Table 10.

In the case of arithmetic, it is evident that the ratios fall close to the critical point; however, we know from inspection of graphs that the line of means is not an approximation to a straight line, and this supports the result of Blakeman's test. Although the evidence is not statistically conclusive, we feel that the value of the correlation ratio is the best measure of the relationship. The curvilinearity is more evident in the case of vocabulary.

Scores of the children in these tests depend, therefore, to a considerable extent upon age. This age effect had to be eliminated in some way in order to compare scores of children and adults. The sex differences were small and inconsistent, hence, in eliminating the effect of age by the sigma score technique, the children were grouped together regardless of sex, to eliminate unnecessary errors of sampling in determining age norms. Table 11 shows the averages for the successive age groups.

TABLE 11

Age group	n	Average arith. score	Average vocab. score
10	13	5.9	48.2
11	14	5.5	47.2
12	13	7.6	63.9
13	21	10.6	77.1
14	35	8.7	77.2
15	31	9.5	87.3
16	31	8.8	90.6
17	26	10.2	96.5
18	27	10.8	98.8
19, 20	37	12.2	99.2
21-30	56	11.8	99.3

TABLE 12

INDIVIDUAL DIFFERENCES

Age group	Range of vocab. scores	Range of arith. scores
10	18 to 90	1.7 to 11.8
11	20 to 89	1.2 to 11.5
12	21 to 94	2.5 to 15.8
13	30 to 98	3. to 18.
14	18 to 106	2. to 15.
15	62 to 114	3. to 15.
16	58 to 114	2. to 19.
17	62 to 118	4. to 16.
18	58 to 114	2. to 20.
19, 20	54 to 114	2. to 20.
21-30	54 to 118	1. to 22.

The ranges of scores shown in Table 12 are approximate, being read from the scattergraph. They are exact for ages 10, 11, and 12. For the other ages, a slight error might be present, because of the grouping into class intervals. The class interval was unity in the case of arithmetic, and four units in the case of vocabulary. These approximate ranges show that individual differences were very great.

In determining the ordinates of the smoothed growth curves for arithmetic and vocabulary, Formulae II and III were used.

$$y = \frac{k_1 a + k_2 b + k_3 c + k_4 d + k_5 e}{k_1 + k_2 + k_3 + k_4 + k_5}. \quad \text{Formula II}$$

$$y = \frac{k_1 a + k_2 b + k_3 c}{k_1 + k_2 + k_3}. \quad \text{Formula III}$$

In these formulae, k_n represents the number of cases used in determining the successive averages a, b, c, etc. The letter y is used to designate the ordinate of the

TABLE 13

Age group	Add.	Sub.	Mult.	Div.	Total arith.	Vocab.
10	4.11	7.36	4.98	6.79	5.81	49.5
11	5.16	7.91	5.81	8.26	6.78	54.9
12	6.22	9.41	6.62	9.71	7.99	66.2
13	7.04	11.37	7.01	10.52	8.98	75.1
14	7.08	11.62	7.13	10.68	9.13	80.3
15	7.25	11.78	7.25	10.77	9.26	85.1
16	7.39	11.88	7.47	10.87	9.40	88.6
17	8.14	12.54	8.36	11.15	10.05	91.9
18	8.90	13.33	9.70	12.17	11.02	95.1
19	9.67	13.96	9.70	12.17	11.38	96.9
20	10.26	14.16	9.70	12.17	11.57	98.4
21-30	11.19	14.59	9.70	12.17	11.91	100.6

smoothed curve. The first formula was used but once in each case, because it is laborious to apply; it was used only because the extreme irregularity of the curve of means seemed to require the application of some powerful smoothing formula. Formula III was applied two or more times. The use of these smoothing formulae results in certain inaccuracies, but in a rough way serves to eliminate gross irregularities due to sampling errors. The resulting curves were not perfectly regular, but were representative of the facts as determined by the data available. For a discussion of such smoothing formulae, see Rietz's *Handbook of Mathematical Statistics*. The means thus determined are shown in Table 13.

Since the changes in variability with age were not great, and, since the number of cases was small at each age group, it was decided to calculate the standard deviations after grouping cases suitably to avoid the effects of too small samples. The results are presented in Table 14.

TABLE 14

Age group	n	*S.D.* for arithmetic tests Add.	Sub.	Mult	Div.	*S.D.* for vocab.
10, 11, 12	38	2.88	3.65	3.19	4.11	22.04
13, 14	55	3.79	4.74	3.42	4.56	16.17
15, 16	62	3.63	4.68	3.53	4.17	12.5
17, 18	52	4.40	4.32	3.75	4.14	12.5
19, 20	36	4.84	4.59	4.45	5.22	12.5
21-30	56	4.49	4.56	4.45	5.22	12.5

The greater standard deviation at the younger ages for vocabulary is due partly to the fact that the test is not sufficiently difficult for the brighter adults. For the older persons, there is a tendency for the distributions to be skewed, since 120 is the maximum score, and the means approach 100 for superior groups of adults. The mean is approximately 91 for college freshmen. There is less deviation above the mean than below. The skewness reduces the standard deviation, but does not cut down the individual differences to such an extent as to affect the reliability coefficients seriously. The high reliability coefficients show that the test has good discriminating power as far as the individuals in this group are concerned.

In the arithmetic scores, the standard deviation increases with age. This is what we should expect, as the increase in means is usually accompanied by an increase in standard deviation. The arithmetic tests seemed adequate for discriminating differences in ability at all levels within the group.

Elimination of the Effects of Age

As a check upon the effects of the sigma score technique in eliminating the effects of age from the scores

TABLE 15

Correlations of Age with Sigma Scores

	Vocabulary			Arithmetic		
	n	r	P.E.	n	r	P.E.
Boys	148	.04	.055	148	.09	.055
Girls	157	.04	.054	157	—.10	.053
Average		.04			—.005	

of the children, the correlations of age with sigma scores were calculated and are presented in Table 15. The regression of course is linear here. The correlations in Table 15 are to be compared with those in Table 10. It is evident that the sigma score technique has eliminated the effects of age from the scores on the tests, as far as one can expect statistical techniques to do it. It is likely that a better procedure would be to take all the children at a given age and avoid the necessity of drawing age curves and getting sigma scores. However, by this method we have succeeded in our purpose of eliminating the effects of age, in order to make the scores of children of various ages roughly comparable.

Summary

The figures presented in the preceding pages of Section III serve to bring out these main facts: first, that individual differences in these test scores are enormous; secondly, that the factor of age cannot explain them entirely; thirdly, that sex differences are insignificant, and very slight in comparison with individual differences; fourthly, that, in the case of adults, the factor of years of education bears little relation to ability in computation but bears an important relation to the scores in the

vocabulary test. This last correlation may be due to the dependence of both factors upon the third factor of biological heredity.

In the case of adults, the factor of age is much less important as far as these tests are concerned. There is a sex difference; the men's scores exhibit a slight decline with advancing age, while the women's scores show no such decline.

The amount of education may have an important effect on the children's scores, but the data are not well adapted to an exhaustive study of its effects. Elimination of the effects of age has apparently eliminated most of the effects of school training.

Since individual differences are very great, the tests highly reliable, and age, sex, and training are not adequate to explain individual differences, we are justified in assuming that they depend to some extent at least upon native differences. Such an assumption is in line with the general trend of evidence available in regard to individual differences, and hence seems perfectly reasonable. To assume the opposite to be true would be much more far-fetched, and would require considerable evidence in justification of the assumption.

If these abilities are dependent mainly upon native endowment, it is important to investigate the relationships that obtain between related persons. At any event, even though one be biased in favor of a "nurture" explanation, the determination of the facts regarding degree of resemblance is a necessary first step.

IV. PARENT-CHILD AND SIBLING RESEMBLANCES

The fact of resemblance between parents and their children can be demonstrated in two different ways: first, by correlation of scores of parents and children; secondly, by studying the members of successive generations to note the presence or absence of a trait. Both methods are used in this study; the second method is not shown at its best except where many generations are available, and is used here in a modified form.

If the traits are inherited, that fact should also show itself in similarities between siblings. Accordingly, in our study by the correlational method we present two types of results, correlations of parents and offspring, and correlations between siblings. In both cases the single-entry method was used in making the scatter diagrams.

In calculating the coefficients of correlation, the total number of pairs has been used throughout. In forming a scatter diagram for a father-son correlation, for instance, the father's score is paired with that of each of his sons. In the case of sibling correlations, the effect is as follows: If there are two children, only one sibling pair is possible; if there are three children in the family, three pairs are possible, etc. This method has the advantage of yielding the largest possible sampling from the available data, and should usually give the same result as other methods of pairing. If there were many large families there might be the objection that those families were too heavily weighted, in securing

the total result, but we do not have any extremely large families. If the method of using only one pair per family, or of using no individual's score in more than one pair were utilized, the number of cases would be smaller, and the probable errors of the obtained correlations would be larger.

Vocabulary

The results or correlating the vocabulary scores of parents and children are given in Table 16.

In presenting our tables of correlations, we have two

TABLE 16

Parent-Child Correlations for Vocabulary

	n	n'	r	Min. P.E.	Max. P.E.
Father, son	116	79	.21	.06	.07
Father, daughter	114	82	.26	.06	.07
Mother, son	126	88	.07	.06	.07
Mother, daughter	136	98	.34	.05	.06
Mean			.22		
Mid-parent, son	116	79	.06	.06	.08
Mid-parent, daughter	114	82	.38	.05	.06
Like-parent, son	116	79	.40	.05	.06
Like-parent, daughter	114	82	.67	.035	.04
Unlike-parent, son	116	79	—.20	.06	.07
Unlike-parent, daughter	114	82	—.02	.06	.07
Mid-parent, child	233	108	.17	.04	.06
Superior-parent, child	86	41	.01	.07	.11
Inferior-parent, child	86	41	.08	.07	.11

The last two correlations were calculated using the data from the 41 families in which one parent was above the average and the other below. There were 86 children in this group. The writer feels that the absence of husband-wife similarity in this group has an important bearing on the correlations. For further discussion of this topic, see Section V.

The correlations of father with son and with daughter in the above table have been calculated after correcting the scores of the fathers for the effect of age. If this correction is not made, the father-son correlation is .04 and the father-daughter correlation is .25.

sets of probable errors: the one we have labelled *Minimum P.E.*, which is the probable error using n, the total number of pairs, is too small; the one labelled *Maximum P.E.*, which is the result using n', the number of pairs possible without taking any individual's score in more than one pair, is too large. The true probable error of the obtained correlation lies somewhere between the two values given. In each case, n is used to indicate the total number of pairs, and n' to indicate the number of pairs possible without using any person in more than one pair. The like-parent refers to the less deviate parent, and the unlike-parent to the more deviate.

The outstanding fact to be noticed is that the correlations are much lower than those usually found. The mean parent-child correlation is .22 There is a difference between the values of the correlations of mother with son and with daughter, a fact which we cannot explain.

The mid-parent–child correlation is .17, which is not significantly different from the mean of the separate parent-child correlations. The coefficients of family resemblance should be calculated separately by sexes. That grouping the sexes together in calculating the correlations of parents and children may conceal some facts, perhaps very important, is indicated by the great difference between the mid-parent–son correlation and the mid-parent–daughter correlation. The correlations of similar parent and dissimilar parent with child are cited for comparison with the results of Cobb, but the present writer does not attempt to interpret these

values to support any particular view concerning the mechanism of inheritance. The last two correlations in the table are given to indicate that, when one parent is superior to the other, there is no significant tendency for the child to resemble the superior one more than the inferior one. Such a tendency might be expected if association caused the resemblance, as it would be very reasonable to suppose the child would seek assistance in lessons, etc., from the parent who exhibited more signs of intellectual superiority. This might be expected to take place especially in regard to special ability in some field, such as arithmetic, or vocabulary.

Treatment of a Selected Group

Because of the diversity of educational experience of the parents, it was considered desirable to study the effects of selection of a more homogeneous subgroup. If we choose within our group a sample more homogeneous as regards education, what will be the effect on the correlations? Only extreme cases were eliminated, as the number of cases does not allow much subdivision. Further work along this line will be done later when a larger body of data is available.

In some cases a bright parent might receive a low score because of lack of education, caused by lack of opportunity to go to school. But if the parent's ability were inherited, the child, having better opportunities for receiving an education, would score high. Thus, in spite of inherited ability, lack of correlation would result from this accident of experience. It cannot be denied that in the state of Minnesota (where this work

was done), and in many surrounding states, educational opportunities were not as great for the preceding generation as they are today. Since an inherited resemblance cannot cause resemblance among related persons unless they have approximately equal opportunity for training, it was thought advisable to exclude cases in which this assumption was violated to too great an extent. Accordingly, all cases in which the parents had less than eight years of education were excluded. One family was excluded because the parents were foreign-born, and the father spent the first fourteen years in a foreign country. In all, 13 families were thus ruled out, leaving 95 families. For this group, the parent-child correlations are shown in Table 17.

The average value of the parent-child correlations has not been changed, in spite of the increased homogeneity of the group. This indicates that in our group the inequality of educational experience for parents and their children has some tendency to cause low parent-child correlations. It is very possible for differ-

TABLE 17

CORRELATIONS IN VOCABULARY SCORES FOR PARENTS AND CHILDREN IN A SUBGROUP MORE HOMOGENEOUS AS REGARDS EDUCATION

	n	n'	r	*Min.* P.E.	*Max.* P.E.
Father, son	100	68	.33	.06	.07
Father, daughter	103	75	.21	.06	.07
Mother, son	100	68	.06	.07	.08
Mother, daughter	104	75	.31	.06	.07
Mean			.23		
Mid-parent, child	204	95	.21	.045	.065

If the fathers' scores are not corrected for age, the father-son correlation is .19 and the father-daughter correlation is .14.

ences in experience to account for the absence of correlation in some cases, but there is little reason for believing that similarities of experience can account for the correlation found in most cases, unless there is also similarity of capacity. In other words, similarity of ability will result from similar training only if there is similarity in the capacity to profit from training; lack of resemblance in ability may result from lack of either of the prerequisites.

The results in Table 17 are to be compared with the results in Table 16. In spite of the decrease in range in the subgroup due to this educational selection, the mid-parent–child correlation is higher here, and the mean of the parent-child correlations is the same as before.

Sibling Correlations

We should expect in advance to find sibling correlations higher than those of parents and offspring, since differences in training and opportunity are greater in the latter case. The resemblance between related persons which is due to innate similarity cannot express

TABLE 18

Sibling Correlations in Vocabulary

	n	n'	r	*Min. P.E.*	*Max. P.E.*
All sibling pairs	210	111	.34	.04	.06
Brother-sister	111	70	.31	.06	.07
Brother-brother	46	37	.43	.08	.09
Sister-sister	53	35	.32	.08	.10
Mean			.35		

Note: The single-entry method was used, the older child's score being represented by the ordinate and the younger child's score by the abscissa, for each respective pair. This method of pairing was used for all sibling correlations in this study.

itself completely unless they have approximately equal training. This condition of equality of training is more nearly satisfied in the case of the siblings. Table 18 shows the sibling correlations for the total group. The average sibling correlation is .35, while the average parent-child correlation was only .22. The lowness of the correlations may be explained partly by the fact that the subjects were highly selected. In regard to the parent-child correlations, we must remember that we have no evidence that the persons concerned had that equality of training which inference as to native similarities from correlation of abilities implicitly assumes. Our average sibling correlation is not far below those reported by Willoughby (62).

We notice that there is no significant tendency for like-sex pairs to resemble each other more than unlike-sex pairs among the siblings. We should expect such a tendency to be evident if association or similarity of environment were the cause of the resemblance; its absence suggests that the similarity is probably due to heredity.

The similarities here found are much like those discovered in early studies of family resemblances in mental and physical traits. We have seen in Section I that the correlations may vary greatly, although, in general, they tend to cluster around .50 for both parent-child and sibling correlations; and that the correlations found in any given case must be considered in relation to the conditions which obtained, before interpretation is attempted. In comparing the correlations found in this study with those found in studies of random groups, we must be cautious and remember that we are

dealing here with a superior group. A hint of the degree of selection is given by the fact that the average number of years of education of the parents is 13.3, which is probably five years more than the mean for the population at large. Such selection helps explain our lower correlations.

Arithmetic Ability

Let us now consider the results obtained with the arithmetic tests. The same method of pairing has been used and the same notation employed. Since the ability of the parents is relatively unrelated to their years of

TABLE 19

Parent-Child Correlations in Arithmetic

	n	n'	r	Min. P.E.	Max. P.E.
Father, son	116	79	.10	.06	.08
Father, daughter	114	82	.04	.06	.08
Mother, son	127	88	.12	.06	.07
Mother, daughter	136	98	.24	.05	.06
Mean			.125		
Mid-parent, son	117	79	.13	.06	.07
Mid-parent, daughter	114	82	.27	.06	.07
Like-parent, son	117	79	.57	.04	.05
Like-parent, daughter	114	82	.70	.03	.04
Unlike-parent, son	117	79	—.32	.06	.07
Unlike-parent, daughter	114	82	—.25	.06	.07
Mid-parent, child	234	108	.19	.04	.06
Superior-parent, child	123	59	.10	.06	.09
Inferior-parent, child	123	59	.04	.06	.09

The correlations of superior parent with child and inferior parent with child in Table 19 are based on the group of 59 families in which one parent was above the average and the other below the average.

The correlations of father with son and daughter are as shown above when the scores of the fathers were corrected for the effect of age. If this correction is not made, the father-son correlation is .08 and the father-daughter correlation is .00.

education, we expect less difference to obtain between the total group and the subgroup. The correlations for parents and children for the total group are shown in Table 19.

Again the correlations are strikingly low, even more so than in the case of vocabulary. The average parent-child correlation is .125, and the only one of any magnitude is the correlation of mother and daughter. However, it is to be noticed that the mid-parent–child correlation in arithmetic is .19, which is just slightly higher than the corresponding figure for vocabulary. (Difference not significant.)

TREATMENT OF A SELECTED GROUP

In the case of vocabulary, the parent-child correlations were calculated again after excluding those cases where the parents had less than eight years of education. The same treatment is here applied to the arith-

TABLE 20

CORRELATIONS IN ARITHMETIC SCORES FOR PARENTS AND CHILDREN IN A SUBGROUP MORE HOMOGENEOUS AS REGARDS EDUCATION

	n	*n'*	*r*	*Min. P.E.*	*Max. P.E.*
Father, son	101	69	.04	.07	.08
Father, daughter	102	75	.01	.07	.08
Mother, son	102	69	.10	.06	.08
Mother, daughter	105	77	.36	.06	.07
Mean			.127		
Mid-parent, child	207	97	.16	.045	.07

If the scores of the fathers are not corrected for the effects of age, the father-son correlation is −.03 and the father-daughter correlation is −.04.

metic data, and, as the reasons for such treatment are set forth in the section dealing with vocabulary, they will not be repeated here. The results are presented in Table 20.

The numbers of cases differ slightly from those for the similar group for vocabulary. This is due to the fact that one family was not included in the vocabulary group because of language difficulty, and because in a few cases a child took the arithmetic tests but not the vocabulary tests. It will be noted that the results for this selected group are in no case significantly different from those for the total group, although the range has been narrowed. We had not expected great differences to result from elimination of some of the variability in education, as it has previously been shown that the correlation of years of education of the parents with their arithmetic performance is slight.

Sibling Correlations

In Table 21 are the correlations of the siblings in arithmetic ability for the total group.

TABLE 21

Sibling Correlations in Arithmetic

	n	n'	r	Min. P.E.	Max. P.E.
All sibling pairs	211	111	.21	.04	.06
Brother, sister	111	70	.17	.06	.08
Brother, brother	48	38	.21	.09	.10
Sister, sister	53	35	.26	.09	.11
Mean			.21		

The average sibling correlation is .21, and those for like-sex pairs are only slightly higher than those for

unlike-sex pairs. No conclusions concerning effects of similarity of environment can be definitely reached from consideration of these slight differences. These sibling correlations are very low; when we consider the selected nature of the group (our total group), this fact is at least partially explained. Starch (53) found a correlation of .32 for the arithmetic ability of siblings, in one investigation, and a correlation of .38 in a second (55) investigation. Lauterbach (30) found the correlations in the case of arithmetic to be .35 for unlike-sex twins, and .69 for like-sex twins. Such results indicate that with less highly selected groups a sibling correlation for arithmetic ability is likely to fall between .30 and .40.

Comparison with Cobb's Results

In presenting her results, Cobb (8) showed only the correlations of the child's score with score of like-parent, unlike-parent, and mid-parent. A certain amount of resemblance in each case might be expected due to the selection of the similar parent. Table 22 shows the results to be expected according to each of three hypotheses, according to Cobb.

TABLE 22

	Correlation of child's score with that of Mid-parent	Like-parent	Unlike-parent
No inheritance	.00	.25	—.25
Inheritance with blending	1.00	.75	.25
Inheritance with segregation	.50	1.00	.00

The results of this study will be placed below for comparison with the results expected according to the three

TABLE 23

	Correlation of child's score with score of Mid-parent	Like-parent	Unlike-parent
Cobb's results:			
Arith. absolute ability	.32	.51	.08
Arith. relative ability	.49	.60	.13
Our results:			
Vocabulary	.22	.54	—.11
Arith. absolute ability	.20	.64	—.28

hypotheses. The correlations were originally obtained separately for the sexes (see Tables 16 and 19), but the averages will be presented in Table 23. It will be remembered that the tests used by Cobb were not the same, but were of nature similar to our arithmetic tests. It is evident here that there is a strong tendency for the children to resemble one parent considerably more than the other. This fact of resembling but one parent is not due to association with the parent of like-sex, as the less deviate parent is sometimes the father, sometimes the mother, irrespective of the sex of the child under consideration. The great difference between the correlations for like-parent and for unlike-parent is possible because of considerable independent variation on the part of the two parents. Cobb has estimated that chance factors would lead to a positive correlation of .25 for child and similar parent, and a negative correlation of —.25 for child and dissimilar parent.

We do not have at hand the data to explain the results completely, but it seems clear that the results obtained in this study are similar to those obtained by Cobb, whether we consider arithmetic only, or whether we consider vocabulary. Cobb concluded that the data best fitted the results expected according to the third

hypothesis. It is likely that those theoretical expectancies are unsound, and represent a gross over-simplification of the whole situation. The results are presented here as empirical facts of interest, without interpretation in regard to mechanisms of inheritance.

Three Types of Matings

It is possible to divide the data into three obvious classes, according to degrees of possession of the ability on the part of the parents. The data for vocabulary will be presented first, in Tables 24 and 25.

TABLE 24

Vocabulary

Case 1. Both parents above the av. 47 families. 98 children.
Case 2. One above av., one below. 41 families. 86 children.
Case 3. Both parents below the av. 20 families. 46 children.

	Parents		Children		Mid-parents	
	Mean	*S.D.*	Mean	*S.D.*	Mean	*S.D.*
Case 1.	56.8	3.03	53.3	9.0	56.8	2.3
Case 2.	47.8	10.3	48.6	10.1	47.8	4.6
Case 3.	39.3	9.0	47.9	10.98	39.3	6.6

Careful study of Table 24 indicates a slight tendency for the variability of the offspring to be related to that of the mid-parent, as well as for the level of ability of the offspring to resemble that of the parents. The fact that we are dealing here with a selected group makes it all the more significant that the ability of the children in each of the three cases deviates from the mean in the direction we should expect if the ability is inherited. The results of further treatment of the data thus classified are summarized in Table 25.

TABLE 25

VOCABULARY

	Case 1		Case 2		Case 3	
	No.	%	No.	%	No.	%
Children above av.	67	68.4	42	48.8	21	45.6
Children below av.	31	31.6	44	51.2	25	54.4
Families having:						
All children above av.	29	61.7	12	29.3	6	30.0
Some above, some below	11	23.4	15	36.6	10	50.0
All children below av.	7	14.9	14	34.1	4	20.0
Families with 2 or more children with:						
All children above av.	16	51.6	8	25.0	3	17.7
Some above, some below	11	35.5	15	46.9	10	58.8
All children below av.	4	12.9	9	28.1	4	23.5
Families with 3 or more children with:						
All children above av.	6	35.3	2	16.6	0	0.
Some above, some below	8	47.1	8	66.7	6	85.7
All children below av.	3	17.6	2	16.7	1	14.3

This table makes possible a large number of comparisons, and they are rather consistently in line with the theory that the ability is inherited. There are, however, a few reversals. Of course, the fact that a family has all children superior, etc., is more significant if it is a large family, but the numbers of cases are smaller for the larger families. The percentages in Table 25 are more suitable for comparisons than are the mere numbers of cases. It is plain that in Case 1, where both parents are superior, there are more superior children than in Case 2, where one parent only is above the average, and that Case 3, where both parents are inferior, produces the smallest proportion of superior children. The differences are slight, but the general trend is clearly marked.

Arithmetic

The data for arithmetic have been classified in the same manner, with the results shown in Table 26.

TABLE 26

Arithmetic

Case 1.	Both parents above the av.	18 families, 41 children.
Case 2.	One above av., one below.	59 families, 123 children.
Case 3.	Both parents below the av.	31 families, 67 children.

	Parents		Children		Mid-parents	
	Mean	*S.D.*	Mean	*S.D.*	Mean	*S.D.*
Case 1.	58.5	5.1	51.8	8.45	58.5	3.2
Case 2.	51.2	8.6	50.0	8.44	51.2	3.6
Case 3.	43.3	4.9	47.8	9.3	43.3	3.2

The level of ability of the children in each case parallels that of the parents, but the children are least variable in Case 2, where the parents are most variable (one parent above the mean and the other below). The

TABLE 27

Arithmetic

	Case 1		Case 2		Case 3	
	No.	%	No.	%	No.	%
No. of children above av.	22	53.6	61	49.6	24	35.8
No. of children below av.	19	46.3	62	50.4	43	64.2
No. of families with:						
All children above av.	5	27.8	20	33.9	4	12.9
Some above, some below av.	8	44.4	20	33.9	12	38.7
All children below av.	5	27.8	19	32.2	15	48.4
Families with 2 or more children with:						
All children above av.	4	26.7	11	26.2	2	8.7
Some above, some below av.	8	53.4	20	47.6	12	52.2
All children below av.	3	20.0	11	26.2	9	39.1
Families with 3 or more children with:						
All children above av.	2	33.3	2	10.5	1	8.3
Some above, some below av.	3	50.0	11	57.9	8	66.7
All children below av.	1	16.7	6	31.6	3	25.0

differences are not great, but they come out in the expected direction. The results of further analysis of the data according to this division are presented in Table 27.

The trend of these comparisons is clearly marked. The proportion of superior children to inferior children is largest in Case 1 where both parents are superior, intermediate in Case 2 where one parent only is superior, and least in Case 3 where both parents are below average.

This indicates that ability in arithmetic depends upon some inherited basis. Under the circumstances, where classification is so difficult, and where the group is so select, it is all the more striking that the differences should come out in the expected direction. We know nothing of the genetic constitution of the parents, who are classified according to degree of possession of the character. Moreover, the classification is arbitrary, anyone above the average being classified as superior, and anyone below the average as inferior. Much of the overlapping is due to the fact that many cases thus classified are very close to the average. Where the parents are really mediocre, the children are likely to be. A better test would be performed by considering only cases where the parents deviated from the average by at least one standard deviation, but to do this would require a considerably larger body of data. We are impressed by the fact that under such adverse conditions the percentages of superior children come out in the expected directions with such consistency. Although the number of cases is too small

in each of our classes after such subdivision to allow us to speak with any great certainty, yet the fact that the tendencies of results are generally as expected supports the theory that the ability is inherited.

Summary of Section IV

Although the correlations found in this study are considerably lower than those usually found, yet there is definite evidence of resemblance between parents and children, and between siblings, both in arithmetic and in vocabulary. For each type of ability the average parent-child correlation is approximately half as great as the average sibling correlation. The correlations for arithmetic are approximately two-thirds as great as those for vocabulary. The conclusion that the similarities found are due to inheritance is supported by the results of study of the three classes of matings.

The fact that the correlations are lower than those usually found we do not interpret as an indication that these traits are inherited to any lesser extent; instead we believe it to be due to some selective factors affecting the data. Our group is certainly very homogeneous when compared with the general population, and this would tend to lower the correlations. Furthermore, if we should be dealing not only with a condition of relatively great homogeneity, but also with a peculiar sampling of parents in the sense that the husband-wife resemblance is unusually low, then the trend of our results might be more readily understood without prejudice to the probable truth of the heredity hypothesis. The whole question of marital

resemblance (assortative mating) thus becomes crucial in the interpretation of the coefficients of resemblance *reported in this section.*

V. MARITAL RESEMBLANCE

There are three possibilities with regard to resemblances between husbands and wives: they may be unlike, due to a tendency for opposites to be attracted to each other; they may be similar, due to a tendency for like to mate with like (homogamy); there may be no correlation present, either positive or negative (random mating).

Studies of marital resemblances have almost always shown that the second condition is present. Husbands and wives are similar, in most physical and mental traits, as pointed out in Section I.

The facts of marital resemblance obviously are related to the question of parent-child and sibling resemblances. The parents both contribute to the child's make-up. If the parents are alike, the child receives inherited qualities which cause him to resemble each parent more than he could if they were unlike. Ellis (10) points out that the degree of similarity of the parents has an effect upon the parent-child resemblance. In this study we should expect this fact to be particularly significant, as the selection of the cases was determined largely by the traits of the parents in one respect. The extent of husband-wife resemblance may help to explain the general trend of our correlations.

Since in both vocabulary and arithmetic we found the child resembled the less deviate parent quite closely, and was not at all like the more deviate parent, we are led to believe that the parents must be rather dissimilar in a great many cases. Let us consider the

resemblances of the parents as indicated by the correlations between sigma scores of husbands and wives. See Table 28.

TABLE 28
HUSBAND-WIFE CORRELATIONS

	n	r	P.E.
Arithmetic, total group	108	−.04	.065
Vocabulary, total group	108	.21	.06
Vocabulary subgroup in which all have 8 or more yrs. educ.	95	.05	.07

At once we see that these correlations are very low. Only one approaches even the low values found in early studies of physical traits. None is nearly as high as the values found in recent studies of mental test abilities.

No doubt this fact has some bearing on the amount of resemblance between parents and offspring and between siblings. In our group there is a goodly proportion of families in which one parent is relatively superior and the other relatively inferior. In such cases the child can resemble one parent or the other, or be halfway between, but cannot resemble both parents closely. This necessarily results in a lower mean parent-child correlation. Undoubtedly it also affects the sibling correlations, for, if one child resembles one parent at random more than the other, and his sibling may resemble only the other parent, the two children will not resemble one another as much as ordinarily, even if all the resemblance is due to inheritance. If there is resemblance due to inheritance, we expect this condition of lack of resemblance between the two

parents to lead to lower sibling correlations and lower parent-child correlations.

In arithmetic the mean parent-child correlation for the total group is .12, and in vocabulary .22. The mean sibling correlations are .21 and .35 respectively. Although the differences are not great, in both cases they are in the same direction, and the higher ones are in vocabulary, where the coefficient of marital resemblance is somewhat higher. Although these differences could result from other causes, it certainly favors the theory that the resemblance between the parents has an effect on the resemblances of related persons within the families. It is to be kept in mind in connection with this discussion, that both tests have unusually high reliability coefficients.

The scatter tables for the correlations between parents exhibit interesting and important facts bearing on the results of this investigation. In arithmetic (Figure 2) the diagram is just an ordinary scatter diagram exhibiting a slightly negative correlation. In vocabulary (Figure 1) it is unusual; there is a clustering of dots in the upper right quadrant, when the table is divided by the lines of means. This tends to cause positive correlation, but the lower right and upper left quadrants also contain a considerable number of plotted points, tending to cause negative correlation. The lower left quadrant shows a conspicuous absence of plotted points in the center, where one would most expect to find them, and this, of course, tends to lower the correlation. If we stop to consider what this means, it reveals some very important facts. We have many

cases where both parents are superior, a considerable number where one is superior and one inferior, and *very few where both are inferior.* In fact, although there are some dots scattered around the edges of the quadrant, there is not one case where both parents are typically inferior so that the dot would fall near the center of the lower left-hand quadrant.

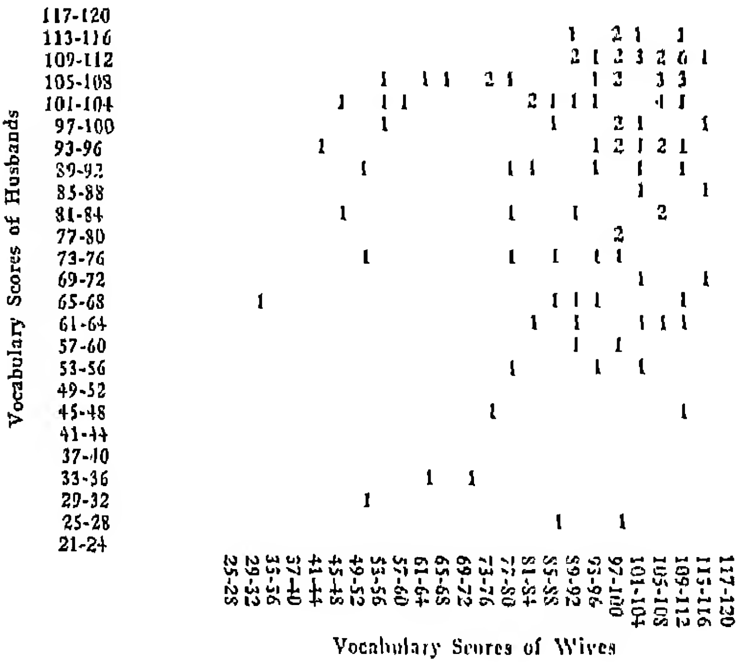

FIGURE 1

MARITAL RESEMBLANCE IN VOCABULARY

The scores of the husbands are the ordinates of the plotted points, and the scores of the wives are the abscissae. The number in each cell is the number of cases falling in that cell. The mean score for the wives is 92.9 and for the husbands is 90.3. The correlation is .21. There is a pronounced absence of cases where the scores of both husband and wife are very low.

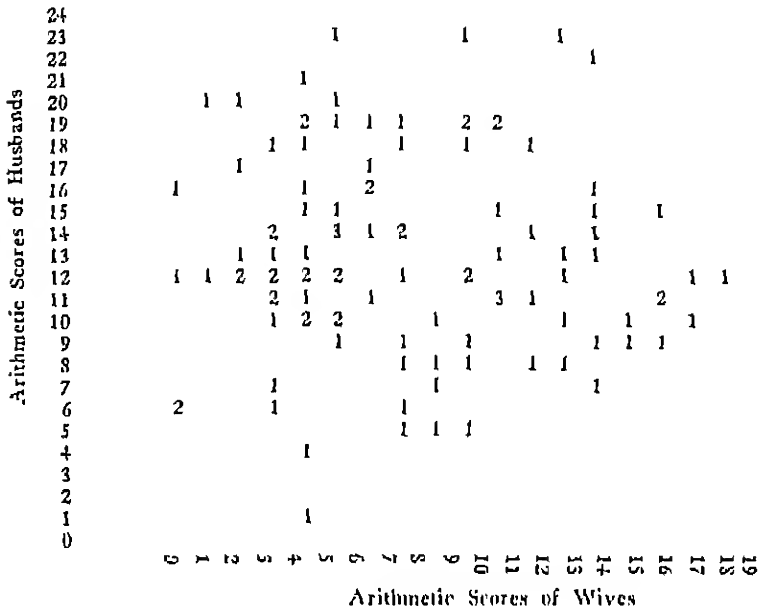

FIGURE 2

MARITAL RESEMBLANCE IN ARITHMETIC

The scores of the husbands are the ordinates of the plotted points, and the scores of the wives are the abscissae. The number in each cell is the number of cases falling in that cell. The mean score for the wives is 8.68 and for the husbands is 13.38. The correlation coefficient is —.03.

This is due, no doubt, to the selection of the cases, which is affected by a number of complex factors. In addition to the cases where the families refused to take the test for reasons apart from their ability, it leads us to expect that the families who refused were those in which both parents are inferior. This does not support the hypothesis presented by others, that the cases lost are those where one parent is unlike the other. It is likely that in these families, which are representative

of successful marriages, one parent can be influenced by the other to a considerable extent. If both are dull, they agree not to bother with the tests, as neither wishes to reveal his inferiority; if both are bright, they agree that it would be interesting, and they cooperate. If one is superior, the other lacking in intellectual ability, the former is able, apparently, to persuade the latter to take the tests.

This conclusion is supported by evidence from the experience of the writer. An attempt had been made to get cases by having students in psychology courses bring their brothers and sisters and their parents to the school to be tested in a group, but this had failed. The method then used was that of individual testing of families at home. A few cases were, of course, easily available, consisting of families who were known by the writer or his friends; from these a list of families likely to cooperate was obtained, and each family tested contributed some additions to the list. First approaches were made by telephone calls, as early experiences seemed to indicate that the best results were to be obtained in this way. Frequently, when cases were suggested for me to test, I would be advised to approach a particular one of the parents, by such a statement as "The husband wouldn't be interested, but if the wife agrees to do it he will do it too," or "The wife is never home, but if you get the husband at his office when he isn't busy he'll make the arrangements, and anyway he is more likely to be enthusiastic about it," etc. Such advice was always carefully followed, and the appeal made to that parent most likely to be

interested. The person tested usually talked the matter over with their friends, and this aided considerably. A small number of cases was secured which the writer feels sure would never have been tested if the other parent had been asked in the first place. The appeal was made to the mothers in the majority of cases, because they were usually easier to reach at home. This has produced no obvious effect on the general results, as the men are not significantly inferior to their wives in vocabulary, and are superior in arithmetic. It might conceivably have something to do with the sex difference in the decline which takes place with increasing age. If we assume that selection took place on the basis of intellect, which would be more adequately revealed by the vocabulary test than by the computation test, it becomes desirable to analyze the discrepancy cases. There seemed to be no consistent relation between the parent who was first approached and the parent who is superior. In a large number of cases, due to their having talked the matter over previously with their friends, it was impossible to say which member of a family probably was most influential in making the decision. Evidently, in order to get a family to take the tests, the necessary condition is to have at least one person in the family who is sufficiently interested to urge the other members to take the tests. There are more cases lost where both parents are below average than where there is a discrepancy. The selective factor, however, may go back even further; perhaps the families were recommended if one or both of the parents are superior, but rarely

TABLE 29

HUSBAND-WIFE CORRELATIONS

	n	r	P.E.
Vocabulary, raw score	108	.21	.062
Arithmetic, raw score	108	-.03	.065
Years of education	99	.37	.058
Age	108	.75	.028

when both are inferior. This too seems likely, and a combination of these several factors probably operated here. The true correlations between married pairs selected at random from the population would certainly be higher than those obtained in this study, for vocabulary at least.

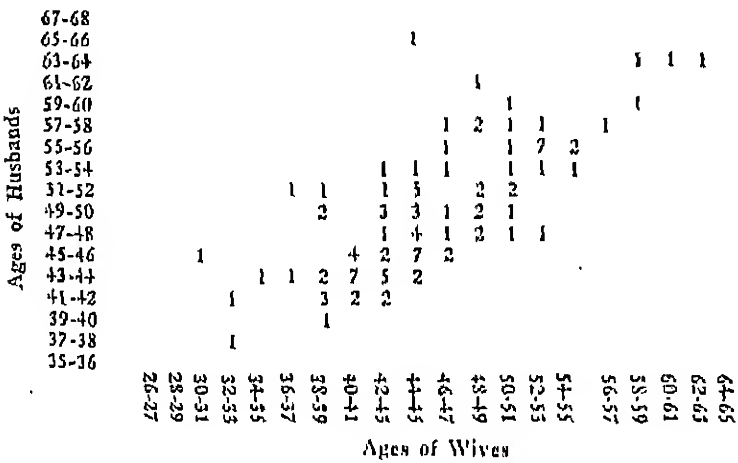

FIGURE 3

MARITAL RESEMBLANCE IN AGE

The ages of the husbands are the ordinates of the plotted points, and the ages of the wives are the abscissae. The number in each cell is the number of cases falling in that cell. The mean age of the husbands is 49.8 and of the wives is 45.8. The correlation coefficient is .75.

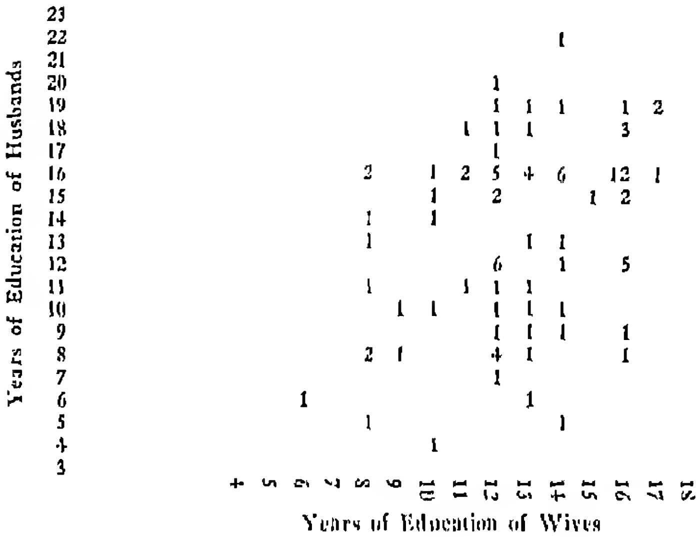

FIGURE 4

MARITAL RESEMBLANCE IN YEARS OF EDUCATION

The years of education of the husbands are the ordinates of the plotted points, and the years of education of the wives are the abscissae. The mean for the wives is 11.0 and for the husbands is 13.6. The correlation coefficient is .37.

For further consideration, let us turn to the correlations shown in Table 29.

It will be noted that these correlations for vocabulary and for arithmetic obtained with raw scores are almost identical with those reported in Table 28 for sigma scores. This is to be expected if no errors are made in the process of getting sigma scores, since in the case of adults the sigma technique was not complicated by the elimination of any age factor.

In mating, there is evidently no selection on the basis

of arithmetic ability. One might, however, expect some similarity due to relation between arithmetic ability and other mental traits. Still, we are not led to expect very high correlations, since ability in the fundamentals of arithmetic is not highly correlated with linguistic intelligence (see 47), and within this highly selected group there would probably be almost no correlation.

The correlation for ages of husbands and wives agrees very well with the result found by Lutz (31). In the present study we have a sample of parents who have children at least 12 years of age, while Lutz dealt with a large group of young married couples. Of course, one expects a high correlation for age, as there are definite, socially recognized reasons for marriage of people of similar ages. Moreover, associations in school, at social affairs, etc., cause one to have more friends of the same age.

We might have expected more resemblance as regards years of education. Goodenough (18) found correlations between education of the mother and that of the father averaging .725 for the parents of preschool children. The difference is probably due to the narrow range of ability in the present study, plus the selective factors involved which apply specially to the husbands and wives, as discussed above. One would expect to find values very high in general, for unselected samples, due both to the unconscious selection of a mate of similar socio-educational status, and to the fact that people have more acquaintances among those of the same grade in school, and more within the

same school system, than in all grades and all schools at large.

It is an interesting fact that the graph in the case of vocabulary exhibited the results of selection more than did the graph for years of education, or any of the others. The fact that the evidence of selection shows up more in the graph for vocabulary may be related to the fact that vocabulary tests are very good measures of abstract intellect. It may also be due to the fact that persons with low vocabulary scores have a handicap of which they are more keenly conscious than are persons who are inferior in some other respect. Vocabulary tests measure abilities which enter into activities of everyday life to a considerable extent.

VI

SUMMARY AND CONCLUSIONS

General Situation

Vocabulary and arithmetic tests were given to a group of subjects including 108 families in which both parents and one or more children were available. A wide range of ability is shown by the scores of both parents and children. Individual differences were very great, and the reliability coefficients were very high.

There have been numerous studies of the resemblances of siblings, but not nearly so many studies of resemblances between parents and offspring, and in only a few of the latter are there any results on the resemblances of husbands and wives. In order to arrive at any adequate understanding of the facts of resemblance and their probable causes, we need a vast accumulation of evidence on all these problems, obtained from all kinds of groups of subjects, and under every type of condition. Moreover, we need such data with regard not only to abstract intelligence, but also with regard to each possible type of special ability.

There are studies showing correlation coefficients of approximately .50 for parents and children, where the groups are relatively unselected. There are also a few studies showing higher correlations where extremes of the population have been grouped together, and lower correlations where the range of ability is more narrow.

However, these last-mentioned studies are not very numerous, and are mostly concerned with sibling resemblances; there are few studies of parent-child resemblances in such situations.

Many problems of daily life are met with in dealing with special groups, and it is undoubtedly important to know what results will be obtained in dealing with selected groups. In order for the chain of evidence to be complete it is necessary to know the resemblances which exist between related persons under all sorts of conditions of selection. We do not doubt that inheritance is present in all such cases; we may find out important facts about our methods of determining its extent, if we apply those methods under varying conditions.

The present study is based on a group of subjects very superior to the general level of the population, and yet showing considerable variation among individuals. Two types of test were used, verbal and numerical. If we find evidence of similarity between related persons with the range of ability thus restricted, the results are all the more important. In such a group the siblings at least have more equal opportunities for developing their abilities. With the range thus restricted, the coefficients of correlation must be lower, and hence the values found require a different interpretation. The resemblance found may be attributed to inheritance, since here there are very few who are deprived of the chance to get training, and similarity of training causes similarity in individuals only if they resemble each other in natural capacity. There is no

evidence to indicate that anything but extremely bad conditions of environment is effective in preventing the development of superior indviduals; here the extremely unsatisfactory environment is not a factor, at least where the siblings are concerned.

The correlations between parents and children and between siblings were all very low. It is likely that this is due to the fact that this group of subjects is highly selected and superior. The selective factors affecting the collection of the data are no doubt the main cause of absence of higher correlations. We are forced to conclude after analysis of the data that there is present a considerable resemblance between siblings and between parents and offspring, but that the correlations are not as high as are usually found, and this is exactly what we should expect to find under the present conditions. It seems probable that this resemblance is due to hereditary capacity, as the results of correlating scores of children with those of like-parent, unlike-parent, and mid-parent are not easily explainable on the basis of training. Moreover, the percentages of superior children resulting from matings of two superior parents, two inferior parents, or one superior and one inferior parent, are such as to support the contention that the abilities are inherited.

Specific Results of the Investigation

1. There is a slight decline in ability with age, on the part of the husbands, indicated by correlations with age of —.25 and —.24 for arithmetic and vocabulary, respectively; the corresponding correlations for the

wives were .09 and −.01, respectively. The husbands range in age from 37 to 66 years, and the women from 31 to 62 years.

2. There is a negative correlation of age with years of education of −.17 for the men, and −.16 for the women. This is probably due largely to the fact that educational facilities were less widespread the farther back we go in the history of the community. The men report from 4 to 22 years of education, and the women from 6 to 17. The average for the men is 13.6 and for the women 13.0.

3. The age of the children is an important factor in ability on these tests. For boys, the correlation between age and vocabulary is .73 for eta, and .62 for *r*. For girls, the corresponding values were .65 and .59. For boys, the correlation of age with arithmetic was .53 for eta and .47 for *r*; the corresponding values for the girls were .36 and .23. The increase in scores with age seemed to extend up to age twenty. Part of this is likely due to education and training.

4. There are no significant sex differences among the children in vocabulary or in arithmetic ability, although there is a slight superiority on the part of the girls in both. In the case of adults, the males are significantly superior in arithmetic ability, which fact is probably due to differences in practice. In vocabulary the women are slightly superior, but not significantly so. The men appear to be the more variable.

5. Years of education of parents is not very much related to their arithmetic ability, the correlation being −.05 for the men and .28 for the women. In vocabu-

lary there is a marked correlation for both men and women, the values of the correlations being .53 for the former and .49 for the latter. This may be partially due to dependence of years of education and vocabulary upon abstract intellect.

6. In the case of the children, years of education is correlated .73 with vocabulary raw scores, and .465 with arithmetic raw score. With the effects of age eliminated, these correlations are reduced to .22 and .12, respectively. This vocabulary test (reliability above .90) would undoubtedly correlate rather high with a test of intelligence, but the computation test probably would not. This indicates that the ability measured by the computation test is perhaps less a function of training than is ordinarily supposed. Since the computation test has a reliability above .90, and it has an average correlation of only .31 with the vocabulary test, the indication is that the two tests measure independent capacities. The available evidence suggests that computation is a special ability.

7. There is a slight resemblance between husbands and wives in vocabulary, as shown by a correlation of .21, but none at all in arithmetic ability, as is indicated by a correlation of −.04. This is probably an important factor in explaining the coefficients of resemblance found between parents and offspring and between siblings in both types of ability.[1]

8. The average sibling correlation is .35 for vocab-

[1]For evidence that the marital coefficients affect all familial coefficients, see references in the bibliography to the articles by Jones (29) and by Fisher (13).

ulary, and .21 for arithmetic. The correlations found in this study are all low, due to the homogeneity of the group (relative to the population as a whole) and to selective factors operating in securing the data, but the fact that they are higher in the case of vocabulary than for arithmetic suggests that assortative mating, which is likewise more pronounced in the case of vocabulary than for arithmetic, is playing an important rôle.[2]

9. The average parent-child correlation is .22 for vocabulary, and .12 for arithmetic, but these values are deceptive. In vocabulary the average correlation of parent with son is .14, and of parent with daughter is .30; in arithmetic, the correlation of mother with daughter is .24, and the other parent-child correlations are considerably smaller. Rather than accept average values, since the various values are so different, the reader should consult Tables 16 and 19. The mid-parent–child correlation is .17 for vocabulary and .19 for arithmetic.

10. There is a pronounced tendency for the child to resemble one parent more than the other. The average correlations are shown in Table 30.

TABLE 30

	Correlation of child with		
	Mid-parent	Like-parent	Unlike-parent
Vocabulary	.22	.54	—.11
Arithmetic	.20	.64	—.28

See Table 22 for Cobb's (8) estimate of the correlations to be expected here by chance if there were no inheritance. The correlations in Table 30 are the

[2]See footnote 1 on page 94.

averages of the values obtained for boys and girls separately. The results are difficult to interpret, but probably the great difference between correlations for like-parent and for unlike-parent reflects to a certain extent the fact of independent variability of the parents. The tremendous variations in ability among siblings are perhaps partly due to this fact also, and on account of both these facts we are led to place emphasis upon the mid-parent-child correlations as the best measures of the parent-child resemblances. It is probably significant that in the case of arithmetic the mother-child correlations are the higher, and the mother's ability is supposedly less a result of unnatural stimulation through occupational effects.

11. Matings of two persons both of whom are superior in these tests produce more children who are superior in these test abilities than do matings of two people either or both of whom are inferior in these test abilities. When the parents were arbitrarily classified as superior when above the average, and inferior when below the average, the matings could be grouped into three classes. Those where both parents are superior should produce the most superior children, if the abilities are inherited. Those where one parent is superior and one inferior should produce fewer superior children, and those where both parents are inferior should produce least superior children. Classification of the children for each of these cases revealed the fact that the differences came out in the expected direction and the results were rather consistently in line with the theory that the abilities are

inherited. This was true of both types of ability studied.

Cause of the Resemblances Found

No particular attempt has been made to evaluate the effects of nurture. "Nurture" arguments have been used by some workers to explain the presence of similarity between related persons; they might conceivably be used to explain absence of similarity. The type of argument usually set forth is inadequate to explain either; that which explains too much explains nothing. The more sensible course is first to demonstrate the existence of similarity, measure its extent, and then search for specific factors in the situation which contribute to the result. Environment as a general term is vague; we need studies to demonstrate the effect of specific environmental factors upon coefficients of resemblance. Such things as parental supervision, school advantages, association with friends of different types, influence of community lived in, and effect of changes of environment should be made the subject of special study. Evidence such as is at present available indicates that the effect of environmental factors is probably slight compared with the effect of hereditary factors. In all probability the effect upon ability-level varies with the type of performance; the effect upon resemblance is another thing, and a more complicated one, involving the natural make-up of the reacting individuals. Separation of the effects of environment and heredity as if they worked in opposition is artificial; analysis to determine how various conditions affect their inter-relationship is much to be desired.

In this study we have demonstrated the existence of resemblance between siblings, and between parents and offspring. We have shown that matings of superior individuals tend to produce superior children, and that matings of inferior individuals tend to produce inferior children, when the parents and children are classified arbitrarily as superior when the score is above the average and as inferior when the score is below the average. We believe that such results are largely due to heredity, but an explanation in terms of nurture is of course a possible alternative.

In searching for specific conditions to explain the fact that our correlations are low, we have found two main ones: first, the relative homogeneity of the group; secondly, the selective factors affecting the collection of data on particular types of families, which are reflected in the absence of a high degree of assortative mating. We have every reason to believe that these abilities would exhibit much higher correlations between parents and offspring and between siblings if a random sample had been secured. The correlations discovered represent minimal values, and further study in which these difficulties are removed will probably support the view that these mental traits are inherited to the same degree as are physical traits such as stature.

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LES RESSEMBLANCES FAMILIALES DANS LES CAPACITÉS VERBALES ET NUMÉRIQUES

(Résumé)

On a fait subir des tests de vocabulaire et des tests de calcul à 108 familles (216 parents, 230 enfants). La constance de chaque test a été plus de 0,90 pour les parents et les enfants dans les groupes homogènes de même âge. On donne des témoignages qui montrent que les deux types de capacité sont relativement indépendants. La capacité de calcul n'a qu'une petite corrélation avec l'intelligence et semble être développée en grande partie au moyen de l'entraînement formel; les tests de vocabulaire sont de bonnes mesures de l'intelligence, et la capacité est développée d'une manière différente.

Dans les deux types de rendement les pères ont montré un abaissement considérable avec l'âge; leurs femmes n'ont montré aucun abaissement semblable. Pour les deux capacités, les résultats des enfants ont eu une corrélation assez élevée avec l'âge et l'année scolaire; quand les résultats ont été corrigés pour l'âge, la corrélation avec l'année scolaire a été très petite. Le nombre d'années d'enseignement des pères ont eu une corrélation de —0,05 avec le rendement de calcul, et de 0,53 avec le rendement de vocabulaire; pour les mères les corrélations ont été de 0,28 et de 0,49 respectivement. Il n'a eu aucunes différences signifiantes de sexe entre les enfants, mais les pères ont été très supérieurs à leurs femmes en calcul.

Les résultats des pères, et ceux des enfants, ont été corrigés pour les effets d'âge. Les corrélations de ces résultats des parents et des enfants ont donné une moyenne de 0,22 pour le vocabulaire, et de 0,125 pour le calcul, quelques valeurs étant plus élevées que d'autres. Les corrélations entre les enfants de mêmes parents ont donné une moyenne de 0,35 pour le vocabulaire, et de 0,21 pour le calcul. Pour les deux types de rendement, une plus grande ressemblance de l'enfant avec l'un des parents qu'avec l'autre a été indiquée, mais les techniques pour l'évaluation de ces résultats se sont montrées insuffisantes. Quand les mariés ont été classifiés en trois groupes (les deux parents supérieurs à la moyenne, l'un supérieur et l'autre inférieur, et les deux inférieurs), les résultats des enfants ont montré un écartement semblable à celui attendu selon l'hypothèse de l'hérédité.

Les valeurs des corrélations sont considérées minimes, puisque les sujets ont été un groupe supérieur, et des facteurs de sélection ont opéré pour produire un groupe de parents où le degré des époux assortis a été moins élevé qu'ordinairement. Les corrélations entre les maris et les femmes ont été de —0,04 pour le calcul, et de 0,21 pour le vocabulaire.

Il paraît que l'inégalité de l'opportunité et de l'entraînement entre les membres de la même famille tend à réduire les ressemblances entre les parents et les enfants. Où il existe l'égalité de l'opportunité, comme entre les enfants, les ressemblances ont été plus grandes. Il y a de grandes différences individuelles de capacité, et des ressemblances familiales précises. L'auteur croit que celles-ci ont une base native, mais il croit que des investigations des effets des facteurs spécifiques du milieu sont nécessaires, si l'on doit séparer les effets de nature et ceux de nourriture.

CARTER

FAMILIENÄNLICHKEITEN IN BEZUG AUF FÄHIGKEITEN FÜR WÖRTER UND ZAHLEN

(Referat)

Es wurden 108 Familien (216 Eltern, 230 Kinder) mit Wortschatzprüfungen und Rechenaufgaben geprüft. Die Zuverlässigkeit jeder Prüfung (test) war über .90 bei Eltern und bei Kindern aus homogenen Altersgruppen. Es wird Beweis dargeführt dafür, dass die beiden Fähigkeitsarten relativ selbständig sind. Die Korrelation zwischen Rechenfähigkeit und Intelligenz ist eine niedrige, und erstere wird mutmassig grossenteils durch regelmässige Einübung entwickelt; Wortschatzprüfungen (vocabulary tests) sind gute Masstäbe zur Messung der Intelligenz, und die Wortfähigkeit entwickelt sich auf eine andere Weise.

Bei beiden Tätigkeitsformen erwiesen die Väter mit zunehmendem Alter eine beträchtliche Verminderung der Fähigkeit; bei ihren Frauen zeigte sich keine solche Verminderung.

In Bezug auf beide Fähigkeiten erwiesen die durch Kinder erzielten Zahlen (scores) eine zeimlich hohe Korrelation mit Alter und Klassenrang (grade location); nachdem die Zahlen in Bezug auf Alter korrigiert worden waren, erwies sich die Korrelation mit Klassenrang als sehr niedrig. Die Länge (Jahren) des Schulunterrichts der Väter erwies eine Korrelation von —.05 mit der Rechenleistung und .53 mit der Grösse des Wortschatzes (vocabulary); bei den Müttern waren die Korrelationen bzwl. .28 und .49. Es zeigten sich bei den Kindern keine bedeutsamen Geschlechtsunterschiede, aber die Väter waren ihren Frauen im Rechnen bedeutsam überlegen.

Die erhaltenen Zahlen (scores) der Väter und die der Kinder wurden in Bezug auf die Einwirkung-des Alters korrigiert. Korrelationen der resultierenden Zahlen für Eltern und Kinder betrugen im Durchschnitt .22 bei der Wortschatzprüfung und .125 bei dem Rechnen; einige Werte fielen viel höher aus als andere. Bei Geschwistern betrugen die Korrelationen im Durchschnitt .35 bei der Wortschatzprüfung und .21 bei dem Rechnen. Bei beiden Arten der Tätigkeit zeigte sich beim Kinde eine Neigung in der Richtung einer höheren Korrelaton mit einem der zwei Eltern als mit dem anderen, aber die technischen Verfahren zur Bewertung solcher Befunde erwiesen sich als ungenügend. Rangierte man die Paarungen in drei Gruppen (je nachdem beide Eltern über dem Durchschnitt, eines über und das andere unter dem Durchschnitt, oder beide unter dem Durchschnitt standen), so unterschieden sich die von den Kindern erhaltenen Zahlen nach der Richtung, die der Hereditätshypothese gemass zu erwarten war.

Die Werte der Korrelationen werden als minimal betrachtet, da die Versuchspersonen einer überlegenen Gruppe angehörten und selektive Einwirkungen tätig waren, die eine typische Auslese (sampling) der Eltern bewirkten wo der Grad der sortierenden (assortative) Paarung minder war als gewöhnlich. Die Korrelationen zwischen den von den Männern und den von ihren Frauen erhaltenen Zahlen war für das Rechnen —.04 und für die Wortschatzprüfung .21.

Es ist wahrscheinlich, dass Ungleichheiten der Gelegenheit und der Einübung bei Mitgliedern der selben Familie dazu neigen, Änlichkeiten zwischen Eltern und Kindern zu vermindern. Wo Gleichheit der Gelegenheit besteht, wie unter den Kindern, sind die Änlichkeiten stärker. Es zeigen sich grosse individuelle Unterschiede in Bezug auf Tüchtigkeit, und auch bestimmte Familienähnlichkeiten. Diese sind, nach der Meinung des Verfassers, im Grunde angeboren, Untersuchungen der Einwirkungen verschiedener Umgebungsfaktore erscheinen ihm aber als notwendig zur Entwirrung der Einwirkungen von Natur und Umgebung.

CARTER

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Child Behavior, Animal Behavior, and Comparative Psychology

THE DEVELOPMENT OF FINE PREHENSION IN INFANCY*†

From the Clinic of Child Development, Yale University

By

BURTON MENAUGH CASTNER

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BURTON MENAUGH CASTNER

CLINIC OF CHILD DEVELOPMENT
YALE UNIVERSITY

CONTENTS

I

INTRODUCTION

The systematic study of behavior development in early infancy, long acknowledged to be of great psychological significance, has been undergoing within recent years a shift of background from the nursery to the laboratory. Extensive day-by-day observation of single children, covering a wide range of behavior, and making use of casual or improvised situations as opportunities occurred in daily life, has given way to planned experiments, limited in the scope of their problems, and made under conditions in which has been apparent increasing and increasingly successful effort to achieve scientific control.

These changes of approach to the problems of infant development have been brought about through a number of causes. The growth of the objective attitude toward psychological problems has tended to call a halt to the earlier extensive and labored efforts to guess what was in a child's mind during a given moment of behavior, and has focused attention upon the importance of the behavior in itself. New experimental techniques, especially adapted to the study of infants, have been devised and applied to problems which it had formerly been impossible to attack in any methodical manner. The downward extension, in point of age, of work in the field of mental testing has called attention to phases of early development in need of scientific study. Finally, the growing interest of the general public in problems of infancy and childhood has

helped in breaking down the formerly widespread prejudice against laboratory experimentation on children. This change of attitude has gone far toward solving one of the most difficult problems that confronted earlier investigators—the problem of securing a sufficiently large number of satisfactorily selected reactors to give significance to the results of an experiment.

The Clinic of Child Development of Yale University has been for several years engaged in an extensive program of research directed toward the establishment of norms of behavior for the period of early infancy. The examinations made in the course of this program are carried on under conditions which permit the application of a considerable degree of control in the various situations. In recording the responses of infants, dictated descriptions of the behavior are supplemented in a large number of the cases by motion-picture records which permit detailed study of the responses at a later time. The conditions under which the examinations are carried out permit of incorporating into them certain experimental situations which it is desired to follow up in still greater detail.

The present study has been made under these conditions. The problem itself is an outgrowth of one phase of the general Clinic research program, and the situation studied is a modification of one which was already a part of the developmental examination. The reactors were selected from among the group being studied by the Clinic. The situation was presented in the course of the complete examination by the regular examiner, under conditions prescribed by the experimenter. The

examiner's dictated account of the child's response is a part of the record of the examination, and has been used to confirm or to supplement the analysis based on the motion-picture records of the response, which have supplied the major part of the data studied.

The purpose of the experiment is to study, by means of motion-picture analysis, the sequence of movements involved in the normal development of fine prehension, as found in infants during the first year of life. By the term "fine prehension" is meant the securing by the hand of small objects, requiring for their efficient prehension a relatively advanced degree of control and coordination of the finer movements of the hand, and especially of the fingers. A detailed description of the experimental situation is given later in the report.

II

HISTORICAL

Our knowledge of the development of reaching and grasping in infancy, as in the case of other phases of development, is based upon three principal types of investigation—(1) day-by-day observations of single children in the natural situations of daily life; (2) normative studies of groups of children at various age levels, conducted for the purpose of test-construction—a special case of the experimental method, but not usually conducted under experimental conditions; and (3) experimental studies made under controlled conditions, of which, so far as the field of prehension is concerned, only a very few have thus far been reported.

Studies Based on Naturalistic Observation

The dates given for the establishment of various responses of infants by those who have reported naturalistic observations are, in the majority of cases, difficult to evaluate to any degree of satisfaction. This is due in part to the casual nature of the situations observed, and in part to differences in the criteria on which the judgments of different observers are based, which are often left unstated. An example of this weakness as a source of confusion may be found in the anxiety of a number of observers to record the precise age at which purpose enters into the response. Thus, in reporting the age at which a grasped object is carried purposely to the mouth, we find Moore (21) placing this response as early as the 6th week, while

others locate it at various ages, mostly between the 12th and 19th weeks. Because of the lack of specific objective description given in these reports, it is impossible to determine from them whether this response actually shows such wide variation in appearing, which seems unlikely, or whether the apparent variability is due to differences in the observers' points of view.

It must be emphasized also that the children whose behavior has been studied in this way cannot be considered as likely to have shown approximately average development. Usually the observers' own children, or close relatives, it would be expected that the majority of them might show a more or less accelerated rate. Thus the absolute dates of appearance of the various phases of behavior cannot be taken as representative of children in general. The order of appearance, however, in those cases where observation and description have been sufficiently complete and accurate, can probably be so taken.

Preyer (25), the first observer whose notes show anything approaching systematic completeness, reported between 20 and 30 observations of grasping made during his son's first year. His summary of the development, while lacking in essential items, indicates in a broad way, for the first time, something of the nature of the developmental sequence involved in prehension. He distinguishes six principal stages:

1. Moving of the hands at random, especially to the face, is inborn and impulsive, determined by position *in utero*.
2. The clasping of a finger placed in the hands in the first days is purely reflex and not to be regarded as

true grasping, which presupposes the perception of a desired object and muscular control, both of which are lacking at that period.

3. Mechanical holding of objects placed in the hand (through the third month) is an unconscious (not yet conscious) movement.
4. Holding with the thumb opposed follows, with grasping upon contact. Holding and clasping no longer take place without consciousness, but are still not voluntary.
5. From the 17th to the 19th weeks participation of the will begins to attain full force. The child does not yet reach for objects, but wills to hold fast the object fortuitously attained. He regards it and forms an idea of it, and from this to grasping on visual stimulation is only a step. With that, purposeful grasping is present.
6. Years pass before this grasping which is indispensable for the development of understanding, becomes perfected and voluntary inhibition of it by new ideas becomes possible.

Shinn (27), following Preyer, recognized the stages of development which he had listed, but was able to add to them in detail. Hers is the most extensive and thorough report on the development of a single child that has ever appeared, and her records on grasping represent a considerable advance over those of Preyer, both in the number and the coherence of her observations and in her analysis of them. She lists the following sequence of stages (Vol. 1, p. 402):

1. Reflex clasping.
2. Hands often felt by lips and tongue, in connection with certain involuntary movements.
3. Renewal of these sensations sought by voluntary repetition of the arm-movements.
4. Sensations increased and varied by touch of objects

accidentally brought to mouth after being mechanically clasped.

5. Deliberate groping for and laying hold on familiar objects in familiar places, to carry to mouth (i.e., repetition of movements that have often resulted in accidentally carrying objects to mouth: extension of the association series).
6. Hands and objects *seen* while grasping takes place; formation of visual association also.
7. Grasping at objects visually located, for sole purpose of carrying to mouth.
8. Grasping for varied purposes, manipulation, inspection, etc., as associations increase in number and variety.

As in the case of most studies of grasping, Shinn's analysis covers with any sort of detail only the earliest months, up to the stage at which definite grasping on visual stimulation is established. She mentions "the slow growth afterward of good coordination between the fingers, and neat grasping," and presents a few observations made during the period of this growth; but the significant changes involved are in general too subtle and gradual in their appearance, and the movements too rapid, to expect any adequate account of them to be obtained from observations of this type.

The numerous notes on grasping reported in Moore's 1896 monograph (21) show careful observation and clear and objective description, with, in some respects, a clearer eye for the significant details of a response than is shown by any others of this group. Her notes of the development subsequent to the establishment of grasping on sight, while not extensive, are well reported and as accurate as could be expected from the standpoint of temporal location.

In the same year with Moore's monograph appeared the first part of Mrs. W. S. Hall's "The First Five Hundred Days of a Child's Life," which, buried in the files of a forgotten and almost inaccessible journal, has merits which entitle it to a place among the classics of its kind. Hall's analysis of the development of muscular movements, including grasping, is based upon degrees of coordination involved, coordination being defined as "the graceful and exact adjustment of muscle movements in time and space." She distinguishes four degrees of coordination on the basis of the number of muscle-groups involved—coordination of the first degree involving one group of muscles; of the second, third, and fourth degrees, involving two, three, and four groups, respectively. As an example of coordination of the third degree she cites the extension and pronation of the forearm, with flexion of the fingers—a movement made in picking up an object from the floor or table. The following conclusions are given (13):

1. The first muscular acts represent coordination of the first degree.
2. The higher degrees of coordination are accomplished in order from the lower to the more advanced.
3. Flexion is earlier developed than the corresponding extension.
4. Adduction is earlier developed than abduction.
5. Symmetrical movements precede asymmetrical ones.

Dearborn's 1910 monograph (7) consists of day-by-day records of behavior, and contains some shrewd observations on grasping; but the usefulness of his reports is seriously limited by the lack of organization and in-

adequate indexing. There is no attempt to summarize the development of prehension.

Dix (8) presents the following interesting summary of the grasping sequence, based upon observations made on his son:

1. Impulsive touching of the face by the hand. Reflex clasping of objects placed in the hand. Lips and tongue feel the hand. (Birth to 1 month.)
2. Accidental prolonged mechanical holding of objects placed in the hand; carrying of these objects to the mouth or letting them fall. Strengthening of sensations. (10th week.)
3. Arbitrary efforts to carry the hand to the mouth. The mouth seeks the breast.
4. Things accidentally seized are held in order to be carried to the mouth . . . Thumb opposition appears. (11th week.)

   Through the above experiences numerous touch sen*sations of movement* become associated and established as ideas.
5. (12th-13th weeks.) Attention begins to play a larger part. Things held are retained and fixated, and the grasping hand is also regarded. Visual sensations associate themselves with touch and active movement sensations, which are established as movement ideas.
6. From the 16th week, grasping for fixated objects in order to carry them to the mouth.
7. (19th week.) The mouth grasps in consequence of strong reproductive data and strong emotional reinforcement. Up through the age of 10 months there is taking place a process of selection and coordination of the grasping movements.
8. By about 10 months of age grasping is perfected as the child forms new associations through reaching out for various purposes.

Myers (22) notes the customary stages of development for the more prominent aspects of prehension,

and states that "by the middle of the year [his child] could readily seize objects within the sweep of either hand, so long as volar movement was not required; and toward the end of the year, the body gradually tended more and more to aid the reaching arm in getting nearer the desired object." Notes on the development of thumb-finger prehension were intentionally omitted from his report.

Simoneit (28), in one of the most recent studies of this type, notes the development of grasping during the first quarter-year of life as passing through the following stages: (1) the holding of an object placed in the hand; (2) the dropping or carrying to the mouth of objects so held; (3) casual contact with objects through movement; (4) reflex grasping of objects so touched; (5) dropping or carrying to the mouth objects obtained in this way. Grasping is still reflex in character at the end of the third month. In the second quarter-year active touching appears, and grasping on visual stimulation develops from the earlier grasping on contact. Feeling with the finger-tips sets in. During the third quarter of the year volitional grasping becomes quicker and surer, and grasping with the finger-tips shows advancement. By the end of the year volitional grasping prevails.

Brainard's study (3*a*) represents an attempt at combining the methods of naturalistic observation and of real experimentation. His report, based on the development of his own child, includes observations on casual reactions, but makes use also of planned situations presented day after day for the purpose of testing

the responses. Much is lacking on the side of control, but, despite this common fault, his paper has many points of unusual interest.

The first stages in the directing of hand movements are more clearly noted by Brainard than they have been by most observers:

4th day: Hand to mouth, with insertion of thumb, as a result of casual movements.

By end of 1st month: Hand motion to mouth accompanied by turning thumb toward mouth.

End of 2d month: Fist clenched and thumb stuck out on carrying hand to mouth.

9 weeks: Hands and feet both moved at sight of bottle; hands open and close.

11 weeks, 1 day: Arms stiffened and moved at sight of bottle.

At the end of the third month a long series of tests designed to show whether or not the child would reach for an object all gave negative results. Just at the end of the fourth month the first positive response was obtained when she crudely grasped a string of beads held before her and carried them to her mouth. From this time on there was rapid progress. At 4 months 11 days, the child reached for a red cube in the experimenter's hand; in this test she sat upright and used an arm movement from the shoulders. At 6 months she reached directly for a spool on the table, grasping it as soon as touched.

Brainard estimates the approximate number of times that the infant's hand touched an object at the same time that the eyes were fixated either on the object or on the hand as follows:

1st month:	0
2nd month:	10

3rd month:	20
4th month:	50
5th month:	200
6th month:	600

Most other studies of the observational type merit mention only because of their historical significance as pioneer studies, and because the total number of observations in the literature is so small that it is desirable to take notice of almost every one that has been made. The notes on grasping in most of them are sporadic and often indefinite; such observations as are actually reported, with dates, are taken into account in the summary at the end of this chapter.

Studies Based on Psychometric Investigations

Those who have devised tests of development for the period of early infancy have almost unanimously recognized in the field of prehension items of value in determining the behavior growth of the individual. In Kuhlmann's scale for the first year of life (18), four out of ten tests comprising the 3-months and 6-months age groups definitely represent stages in the development of prehension. Kuhlmann himself points out that these tests were only very roughly standardized in comparison with those at the higher levels of the scale, having been originally drawn up through a study of the observations of Preyer, Shinn, and others, and tried out on a small and unrepresentative group of infants. As the first tests provided for the early age levels, they served their purpose of detecting the more marked deviations from the normal, which was all they were

intended to do; but they have added nothing to our knowledge of the development of prehension.

The preschool tests described by Gesell (10) represent the first extensive attempt to devise norms of behavior for the earliest age levels. Scores of items make up the test-schedules presented for the ages studied during the first year (neo-natal, 4, 6, 9, and 12 months), and these include a number of definite developmental sequences, among which that of prehension, in the more advanced as well as the earlier stages, has a prominent place.

The preliminary standardization was made on 50 apparently normal children at each level studied. On the basis of the clinical application of these tests, together with comparative studies of children at successive age levels, a tentative scale of monthly increments of development up through 10 months was constructed (11). The items more directly involved in the development of prehension are the following:

1 month:	Gives transient visual regard to the red ring.[1] Retains definite hold of the ring when it is placed in the hand.
2 months:	Makes vertical thrusts in random play when in dorsal position.
	Gives prolonged regard to dangling ring.
3 months:	Varied tactile manipulation of ring. Fingers one hand with the other in tactile motor play.

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[1] The test-objects referred to are the following: *Ring*: A bright red wooden embroidery ring, outside diameter 11 cm., with white string 25 cm. in length attached. *Cube*: Bright red wooden cubes, 2.5 cm. square. *Pellet*: A white sugar pellet similar to the ones used in the present experiment, but slightly larger (diameter 8 mm. instead of 7 mm.).

4 months: Closes in with both hands on dangling ring when in dorsal position. Regards 1-inch cube on table. Inspects own hand.

5 months: Picks up cube from table *on contact*. In dorsal position recovers rattle fallen within easy reach. Makes reaching approach to sheet of paper favorably presented. Eyes cooperate in prehension and manipulation.

6 months: Grasps with simultaneous flexion of the fingers. Retains transient hold of two cubes, one in each hand. Reaches for object *on sight*. Picks up cube from table on visual cue. Regards pellet on table surface.

7 months: Tends to unilateral reaching and manipulation. Rotates wrist freely in manipulation. Secures pellet with raking or scooping palmar prehension. Picks cube deftly and directly from table. Reaches persistently for remote cube. Manipulates ring with sustained inspection. Plays exploitively with paper and string.

8 months: Picks up pellet with partial pincer prehension. Utilizes handle in lifting inverted cup.

9 months: Opposes thumb in seizing cube.

10 months: Plucks pellet with precise pincer prehension.

In this series the following stages in the development of grasping can be differentiated:

1. *The development of selective regard for seizable objects* of various sizes from larger to smaller—for the ring at 1 and 2 months, for the cube at 4 months, and for the pellet at 6 months.
2. *The development of reaching for objects—closing in* with both hands on the ring at 4 months, reaching for a sheet of paper at 5 months, for the cube and other objects on sight at 6 months, unilateral reaching at 7 months.
3. *The development of grasping* with the hand and fingers—reflex clasping of the ring at 1 month, with

varied tactile manipulation of it at 3 months; picking up the cube on contact at 5 months, on visual cue at 6 months, "deftly and directly" at 7 months, with opposing thumb at 9 months. The pellet is secured with raking or scooping palmar prehension at 7 months, with partial pincer prehension at 8 months, and with precise pincer prehension at 10 months.

These figures have been offered as representing an approximate allocation of the various responses to their age levels, and are to be modified, where necessary, in a forthcoming study based on research which has been in progress several years. In their present form, however, they represent the most complete analysis of different phases of the development of prehension that has thus far been made on a large number of children, and they furnish a valuable starting point for more intensive studies.

Linfert and Hierholzer (19) gave a series of tests, based in part upon Gesell's scale, to 50 children at each of the following ages: 1, 2, 4, 6, 9, and 12 months. The children were mainly from approximately average homes, with a small admixture from an infant asylum. The significant prehension items were, for the 1-, 2-, and 4-months levels, grasping a ring placed at the fingertips, and carrying the ring so held to the mouth. For the 6-, 9-, and 12-months levels, the item of the greatest interest here is regard for a pellet. The size of the pellet is not given; it differs in form from the one used in the present study in being flat on both sides, which of course is of negligible significance when the question is purely one of regard.

At the three earlier age-levels Test 4 (grasping ring

on contact) was passed by 62%, 76%, and 98%, respectively, of the children tested. Test 11 (carrying ring to mouth) was passed by no children at 1 month, by 2% of the 2-months group, and by 30% at 4 months. The pellet was definitely regarded in 36% of the 6-months cases, and by all the older children studied.

These investigators have given fewer tests from the field of prehension than any others who have presented scales of tests for the first year of life. Their inclusion of the pellet represents its only appearance in the literature outside the work of Gesell, and the study is therefore of especial interest in connection with the present experiment.

The infancy tests of Hetzer and Wolf are based upon the studies of Charlotte Bühler, and contain a fairly large proportion of prehension items. The children observed were in the *Kinderübernahmstelle*, Vienna, and were presumably considered as average. The location of the test-items was based on the examination of 40 children at each age level. The following prehension items are included (there are no tests for 1 month):

2 months:	Fixating on an object (a 3½-inch disc covered with tinfoil). Experimenting movements—"slow, quiet movements, which the child himself observes."
3 months:	Feeling of objects (active touch).
4 months:	Grasping (a rattle) with both hands, without using fingers. Grasping on contact. Looking at an object (rattle) while moving it. Manipulatory movement of an object (rattle).

5 months:	Grasping an object on sight with one hand, or with both hands, using fingers.
6 months:	Grasping table edge.
7 months:	Moving toward a desired object by change of position (while lying down).

We note here again the lack of attention given to the later stages of development, subsequent to the establishment of grasping on sight. The participation of postural adjustment as a phase of the prehension sequence, which is noted at 7 months, furnishes a new item, but otherwise the scale makes use only of the familiar early stages.

Figurin and Denisova (9), in preparing their diagnostic outline of behavior up to one year of age, observed about 20 Leningrad children at each lunar month interval during that period. Their outline aims to include not only the date of establishment of a response, but also the age at which it first begins to appear, and its stages of development.

Visual fixation on "a bright object," held from a quarter to half a meter before the child's eyes when he is in the dorsal position, is found to occur first at about the end of the 2d week. The time of fixation is at first from 5 to 10 seconds, later as long as a minute and a half. By the end of the 8th week the response was present in all cases.

Excitement in the presence of a desired object usually starts to appear by the end of the 2nd month, and is present in 100% of cases by the middle of the 4th month. It is shown by such behavior as excited waving of the arms, flexion and extension of the legs,

and fast breathing; the first stage is a slow moving of the hands and brightening of the facial expression.

Reaching for an object held just within range of the child's arms (it is not stated whether the dorsal or the sitting position was uniformly used) begins to appear in rudimentary form in some children as early as the middle of the 2d month, and is found by Figurin and Denisova to be present in all their cases by the end of the 4th. At first the response is characterized by excitement and increase of activity (see above), then the child puts his hands out and touches the object. Later he keeps his hands on the object and starts to manipulate it, but he cannot yet hold it by himself, and will drop it if it is released by the examiner.

The psychometric method may, if applied with adequate precautions as to control, and with some forethought in devising situations, make an important contribution to our knowledge of infant development; and such precautions will also result in the formation of better tests. This double purpose will be served (*a*) by using all the methods of standardizing conditions and procedures which are practicable in situations to be used for purposes of clinical testing; (*b*) by using age intervals short enough to catch the significant changes in the development of behavior, which take place relatively swiftly at this early level; (*c*) by including in the scale tests which will demonstrate the important successive stages in definite genetic sequences; (*d*) by publishing as completely as possible the details of the various gradations of behavior ob-

served, with objective statements of the criteria used; (*e*) by using definite, stated, criteria for the selection of the infants studied.

Experimental Studies

An early experimental study of the development of prehension was made by Watson (33, 34) on 15 infants, using a stick of red peppermint candy as the stimulus-object. The child was held seated in the mother's lap and the candy dangled before him on a string. After each failure to grasp, a conditioning factor was introduced by putting the candy into the child's mouth. Observations were made at weekly intervals.

A representative reactor from Watson's group was examined each week from the age of 101 days (15th week) to 171 days (25th week). No evidence of reaching was obtained until the age of 122 days, although in the first experiment "on the last trial she seemed to open her hand and make tentative striking movements." At 122 days there were three definite attempts to grasp after the candy had been put momentarily in her mouth; one of these attempts was successful. The response showed increasing directness and accuracy thereafter, and was considered as well established, as in the case of all the reactors, by 150 days (22nd week). The conditioning factor does not seem to have affected the results significantly, since the ages given are in essential agreement with those generally reported.

An experiment on reaching reported by Jones (16) is especially valuable because of the simplicity of the situation used, the large sampling of reactors, and the

completeness of the report. Nearly 500 reactors were employed, ranging in age from 80 to 290 days, and obtained through New York baby welfare clinics. The stimulus-object used was a bright toy, moved slowly along a line between the child's eyes until it came within reach. The child (in the dorsal position in the majority of cases) was allowed 10 seconds in which to grasp the object; ten such trials were made in each case.

The youngest child to pass the test within the 10-second limit on any one of the ten trials was 116 days of age (17th week). The response was present in 25% of cases by 135 days (20th week), in 50% by 152 days (22d week), in 75% by 173 days (25th week), and in 100% by 269 days (39th week), the percentile figures being smoothed curve values. The quartile deviation was 19 days. Thus the middle 50% of cases developed the response within a range of 5 weeks.

Thumb-opposition in grasping showed, according to Jones, a curve of development almost identical with that of reaching, the earliest appearance being in an infant 108 days of age, and the 100% mark being reached at 266 days. The middle 50% developed this response between the 19th and the 26th weeks. The reaction was tested by placing a 1-inch cube, a 1-inch rubber ball, and a pencil, in first the right hand and then the left.

Halverson's study of development in cube-prehension (14), recently published as one of the *Genetic Psychology Monographs,* represents the most ambitious experiment so far made with the purpose of analyzing

behavior growth in the field of grasping. Using red cubes 1 inch on a side as his stimulus-objects, he studied the reaction of 12 or more infants at each of 8 age levels during the first year in three prehension situations. His experiments were made under conditions similar to the one which is the subject of the present report, and made use of similarly selected reactors; while begun some time before the present experiment, they were carried on in part simultaneously with it. The major plan of procedure followed herein and many of the special techniques employed have been taken, in the original or in modified form, from Halverson. Because of the similarities of situation and method, his results will be discussed at length, where appropriate, in connection with those here reported.

A Comparative Summary of the Development of Prehension, Based on the Literature

The information contained in the literature as to the dates of establishment of the responses most significant in the development of grasping may be summarized here, despite the fact that, for reasons already mentioned, the figures given can be considered only roughly comparable.

It is agreed that practically all normal infants from birth will close the hand around an object pressed against the palm, and that this clasp is in most cases strong enough to support the infant's weight (33, p. 241). While this reflex clasp has generally, following Preyer, been distinguished from true grasping, it should probably be considered as a foundation for the

developmental sequence which culminates in grasping on sight, and as the essential factor in the first grasping on contact. Watson reports that the reflex is present in more or less perfect form up to about the 120th day or longer, and that it seems to give way about the time the eye-hand coordination is established.

The first practice in directing the movements of the hand seems to occur in connection with *carrying the hand to the mouth*. Brainard (3*a*), in the notes already mentioned, finds this developing during the first two months, with increasingly efficient guidance of the movement to bring the thumb into the mouth. Carrying hand to mouth with apparent intention has been reported by Hall as taking place in the 8th week, by Shinn in the 9th and 10th weeks, respectively, in two cases, and by Moore in the 10th week.

Grasping on casual contact is located in a number of observations between the 10th and 13th weeks, although Moore, whose dates in general seem to run earlier than others, placed it between the 6th and 8th weeks. *Adjusting the hand to grasp* an object contacted otherwise than against the palm was noted by Sully and Shinn in the 11th and 12th weeks, respectively, while Dearborn did not observe the response until 17 weeks. Gesell places the test of picking up a 1-inch cube on contact at 5 months.

Carrying objects (purposely) to the mouth has been reported with wide divergence as to the observed age (the studies by Sharp, Tilley, and Wood are parents' records cited by Shinn):

6th week:	Moore
11 weeks:	Dix

12th week:	Hall, Darwin
13th week:	Shinn
At 3 mo.:	Sharp
14th week:	Tilley
At 4 mo.:	Wood
At 4½ mo.:	Wood (2nd case)
19th week:	Sully, Beatty

During these early stages of clasping, holding, and carrying to the mouth, there is increasingly present, after the first month or so, a visual component of the response. The first definite *fixation on objects* (other than following a moving object, which may take place, in the case of a light, on the first day) seems to occur about the middle of the first month (Gesell, Stern), and is at first for relatively large bright objects. *Fixation on a grasped object* appears during the 4th month (Dix, Brainard, Shinn, Moore), and at about this time the grasping hand is also regarded after contact has been established. This is the preliminary stage to grasping on visual stimulation.

Preceding visual-motor grasping, however, there is a stage in which the infant shows an *increase of activity,* with evidences of excitement, in the presence of a stimulating object. Brainard observed this in the presence of the child's bottle at 9 weeks. Figurin and Denisova found it in some cases during the 2d month, and in all cases by the end of the 4th. Increase of arm and leg movements, with opening and closing of the hands, is prominent in this heightened activity.

The activity soon begins to take the form of a crude *groping toward the object.* This is true reaching,

lacking only the ability to direct the movements accurately. It is reported at the following ages:

8th week:	Ament
11th week:	Scupin
12th week:	Moore, Major (doubtful)
Early in the 4th month:	Simoneit
16th week:	Major (definite)
At 16 weeks:	Shinn

Gesell found a closing-in of both arms when a red ring was dangled over an infant in the dorsal position, in between 20% and 50% of his cases at 4 months; he states that definite reaching is not to be expected at this age. The response noted by Brainard just at the end of the 4th month, when his child with difficulty secured a string of beads held before her, is apparently of the same groping type; a string of beads would be rather easier to secure in this way than most objects which have been used.

The dates reported for the establishment of *grasping an object visually located* are as follows:

10th week:	Ament
11th week:	Hall, Alcott
12th week:	Moore
16th week:	Scupin, Dix
17th week:	Shinn (1st case), Preyer
18th week:	Myers, Dearborn, Watson
19th week:	Sully
19 weeks:	Sigismund
20th week:	Major, Shinn (2d case)
In the 5th month:	Simoneit

Gesell and Kuhlmann place tests of this ability at 6 months, Hetzer and Wolf at 5 months.

With the establishment of visual-motor grasping,

bringing us down to the age level at which the present experiment begins, most observers have been content to leave the systematic attempt to record the development of prehension. Gesell and Halverson have carried on through and beyond the first year. Others have found the changes taking place after about 5 or 6 months too difficult to follow, except in very broad outline. Shinn, for example, states:

> "Her skill in grasping when the finger-tips alone could be used, perfected but slowly: In the thirty-fourth week she tried unsuccessfully to pick up tiny scraps and thrums, say ¼ inch in diameter, from the floor; in the thirty-sixth (249th day), she picked up a small tack and a pin with ease; and at thirty-eight weeks old she played with a single hair and with a wisp of thread scarcely larger than a pinhead. Even at fifteen months old, however, I saw her make several efforts before she could pick up a small shot."

The reports of other observers will be cited, where relevant, in connection with the results obtained in the present experiment.

III

THE EXPERIMENT

The aim of the present experiment is to study, by means of the analysis of motion-picture records of behavior, the sequence of movements involved in the normal development of fine prehension, as found in infants during the first year of life.

By the term "fine prehension" is meant the securing by the hand of small objects, requiring for their efficient prehension a relatively advanced degree of control of the finer movements of the hand, and especially of selection and control of the fingers. The object chosen as the stimulus for prehension is a round white candy pellet, approximately 7 mm. in diameter, flat on one surface and convex on the other,[2] which is placed before the seated infant on a table top, under standardized conditions.

The pellet was chosen as a stimulus-object for a number of reasons: (1) It is an object the efficient prehension of which requires precisely the type of behavior which it was desired to study. (2) It was desired to utilize a situation which was already part of

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[2]The pellets used in this study were cachous manufactured by Smith and Peters of Philadelphia, and purchased from Rexall drug stores. Those bought at different times have shown considerable variation in size and shape, but the ones used during the experiment were obtained all at the same time, and were relatively uniform in these respects. Twelve samples, selected at random and measured by placing them on a millimeter scale, showed the median, mode, and mean of the diameters all to be precisely 7 mm., with a mean variation of .125 mm.

the Yale developmental series, that the experiment might bear a close relation to the general research program of the Clinic. (3) Preliminary experience with the pellet had indicated that infants of the ages in question responded satisfactorily to it, and that their responses at various age levels constituted a genetic sequence sufficiently clear to warrant thorough study and analysis. (4) It is a type of object with which infants are relatively unfamiliar; children below the age of 1 year are not ordinarily given loose objects comparable in size to the pellet as playthings. (5) It is quite harmless to the child, even if taken into the mouth and swallowed—a consideration of distinct importance.

The Reactors

The reactors were infants who were being used in the general program of normative research already under way at the Clinic. These infants have been selected with a view to obtaining a relatively homogeneous group from the standpoint of race, home environment, and family background. They come from Teutonic or Celtic stock, the fathers' occupations all fall within the middle 50% on the Barr occupational rating scale (32), and the parents' education has commonly been of the grammar-school level, with, in a few instances, some high-school or equivalent training. Thus the aim has been, as far as parental occupation and education can be taken as an index, to obtain children of these racial stocks whose family background is suggestive of an average level of intelligence. Premature

and post-mature children were omitted as well as any who had suffered from extreme illness or malnutrition.

The age levels chosen for study were 20, 28, 32, 36, 44, and 52 weeks. The 32-weeks group was added after a consistent 8-weeks interval had originally been planned, because of the rapidity of the behavior changes taking place at about that age. Twenty weeks was chosen as the lower limit because it is the age at which definite response to the pellet first appears in a large proportion of cases, while only occasionally would a completely successful reaction be found under the conditions of the experiment. The upper limit was placed at 52 weeks because at that age the response is found to have developed into a smooth, well-coordinated bit of behavior through which the pellet is secured efficiently and quickly.

TABLE 1

SEX DISTRIBUTION OF THE REACTORS BY AGE GROUPS

Age in weeks	20	28	32	36	44	52
No. of boys	6	4	5	6	6	4
No. of girls	4	5	5	4	4	6
	No. of boys		31			
	No. of girls		28			
	Total		59			

Table 1 shows the sex distribution of the reactors to be about even, with a slight preponderance of boys over girls in the entire group, and at three of the six age levels. The proportion of one sex to the other, however, is in no group greater than 6 to 4. Thirty-two different children were used in the experiment, but no one child appears at all the levels studied, and no attempt is made

in this investigation to follow any child through successive stages. Each child is considered as a different reactor in each age group in which he appears. There *are 10 reactors in each group for 20, 32, 36, 44, and 52* weeks, and 9 at 28 weeks.

Table 2 gives the Barr scale ratings of the fathers' occupations for all cases. On this scale, occupations are given ratings of from 1 to 20, from the lowest to the highest. Terman (32), on the basis of census reports from the three largest California cities, found the mean for the total adult male population of those cities to be 7.92 by one method, and 8.88 by a second method; he seems to consider that the lower figure is probably a closer approximation to the true mean. Our average rating for all cases is 8.89, with a mean variation of 1.31; the group may therefore be taken as closely approximating the average, so far as paternal occupation is an index.

TABLE 2

OCCUPATIONAL RATINGS OF FATHERS OF REACTORS
(Based on the Barr rating scale)

Age group / Reactor	20	28	32	36	44	52
1	7.39	10.11	7.05	9.37	10.26	8.75
2	8.89	9.72	7.39	11.34	10.24	10.26
3	7.17	9.72	10.26	6.27	7.17	7.39
4	11.51	8.08	10.24	10.24	10.26	9.72
5	10.26	7.54	9.72	10.26	10.26	9.72
6	9.72	5.89	8.89	8.89	9.72	10.26
7	10.11	10.26	10.26	7.02	7.39	9.72
8	5.89	7.05	9.37	9.72	10.11	6.27
9	10.53	8.89	10.11	5.89	7.02	6.27
10	7.54		8.08	8.08	9.72	8.89
Average	8.90	8.59	9.14	8.71	9.22	8.80
		Average for all cases		8.89		
		Mean variation		1.31		

While complete data are not yet available for the normative examinations in connection with which these experiments were made, it can be said that none of the reactors used have given evidence, in the course of them, of any marked deviations from the normal developmental rate.

All infants were examined within two days of the exact ages at which they are placed.

The Experimental Situation

The Environment. The situation was presented in the photographic observatory of the Clinic of Child Development (11, 13*a*) in the course of a complete normative examination. From the inside, i.e., from the reactor's point of view, the observatory (more conveniently referred to as the dome) is a brightly lighted room, with a circular floor 12 feet in diameter, and with white walls which, after rising vertically for 32 inches, continue upward as a hemispherical dome. The walls consist of a fine mesh screen, attached to the heavy iron framework of the structure and coated with white paint. When the interior is well lighted and the surrounding room outside is dark, the screen appears to observers within as a solid wall, while permitting a high degree of visibility to those outside. Thus potential distracting features of the environment, as it appears to the infant, may be kept at a well-controlled minimum, while any amount of relatively noiseless activity that is necessary for observing and recording the responses may take place outside the dome.

Lighting was furnished by 8 Cooper-Hewitt

mercury arc lamps supplemented by 24 50-watt incandescent lamps, which were added to restore chromatic values lost when the mercury arc lighting is used alone. The reactors were shielded from the direct glare of the lamps by white tissue-paper screens, giving something of the effect of translucent windows. The lights were grouped in two batteries. One, consisting of 6 Cooper-Hewitts and 18 incandescents, was located above and slightly to the right of the child as he was seated in the experimental position; the second, made up of the remaining lamps, was above and at the far right. The flat white paint with which the inside of the dome was covered served to reflect and diffuse the light in such a way as to prevent the light-sources themselves from standing out too prominently. As a matter of fact, the motion-picture records of the infant's behavior reveal that the lights had very little distracting effect.

The slot made in the side of the dome by the camera tracks (13*a*) was concealed by heavy white cardboard, with a small opening left at the desired camera position through which to photograph. The motion-picture camera itself was enclosed in a box which thick padding had rendered nearly soundproof. As in the case of the lighting, it was found that the noise of the camera did not act as a distraction. The risk of other distracting noises from outside the dome was reduced by a thick soft floor-covering.

Preliminary Procedure. On arrival at the Clinic, the infant, with his mother, is conducted to the dome, where he is undressed and allowed a period for adjust-

ment to the new environment before the examination begins. Due precautions are, of course, observed at all times for his physical welfare. The pellet situation occurs at a point about midway in the total examination. It has been preceded, in the case of 20- and 28-weeks infants, by a short series of tests presented in the dorsal position, and at all ages by a series in the sitting position. There has been ample time allowed for adjustment to the situation, but not enough, in the case of most children, to cause apparent fatigue.

The previous test-situations presented to the child, which involve his response to an object placed before him on the table top, make use of 1-inch red cubes, an ordinary teaspoon, and a white enameled cup. The test-objects presented immediately prior to the pellet are the cup, at 20 and 28 weeks, and the cup and cubes together at the higher levels. If, for any reason, it was found necessary to interrupt the examination just before the introduction of the pellet, the preceding situation was always reinstated and carried through again before beginning the experiment.

The Pellet Presentation. For this experiment the child is seated on the 30-inch-high platform of the experimental crib, facing and just not touching a table top, which is supported on the adjustable side rails of the crib at the height of his elbows. If the infant is able to maintain a steady sitting posture without support, he is seated on the platform of the crib; the younger children who cannot sit alone are placed in a small morris-chair, devised especially for this purpose, supported by a comfortably wide canvas belt around

the waist. This arrangement is illustrated in the photographs reproduced in Figures 5 and 6 on page 174. It is almost never necessary to use this chair at an age level as high as 36 weeks.

The table top (20 inches x 30 inches in size) is painted the same neutral gray as the experimental crib. Its surface is divided laterally into 6 equal lanes by lines which extend from the far edge, opposite the reactor, to a horizontal line parallel with, and 6 inches from, the near edge. These lines facilitate the analysis of the photographic records, and seem not to interfere with the infant's natural responses to the objects placed before him.

The method of presenting the experimental situation is as follows: The infant's hands are first quickly and thoroughly wiped with a soft pad which has been dusted with talcum powder, in order to prevent the pellet from sticking to the moist hand. The examiner then immediately takes the pellet in her left hand (she stands at the child's left side throughout the examination) and taps it against the far end of the table to attract the child's attention. As soon as he regards the hand holding the pellet, it is advanced along the median line, thumb and index-finger holding the pellet in advance of the rest of the hand, to a point 6 inches from the near edge. This forward movement of the pellet is timed to take approximately 2 seconds. Reaching the point described (hereafter referred to as the *standard median position*), the pellet is left on the table top, resting on its convex surface, and the hand is withdrawn smoothly and quickly.

At the instant the hand starts to carry the pellet forward in presenting it, the motion camera and a stop-watch are started simultaneously by the operator outside the dome. At the end of 9 seconds the operator says "Now," in an ordinary low tone; if by the time this signal is given the child has not succeeded in prehending the pellet, or if he has knocked it definitely out of reach without having secured it, it is then taken up by the examiner and advanced directly forward from the standard position to a point 3 inches from the edge (the *near median position*) and left as before. Thus the infant who is unable to direct his arm and hand movements to secure the pellet is given a second opportunity at closer range. In practice, the change to the near median position was not found necessary above 28 weeks.

The camera record was discontinued (*a*) if the pellet was knocked, dragged, or dropped below the table surface, or carried to the mouth; (*b*) in the event of any happening which interrupted the normal conditions of the experiment, such as a loud sound, or a disturbance of the reactor's equilibrium necessitating the examiner's intervention; such episodes were discarded from the experimental series; (*c*) if the response to the pellet was interfered with by fussing or crying; (*d*) at the end of 20 seconds at 20 and 28 weeks, or at the end of 40 seconds at the higher ages.

The original plan of procedure called for continuing the episode for 40 seconds at all ages. It was found, however, at 20 and 28 weeks, that 20 seconds was ample to demonstrate the best response which the child was

able to make, and that continuing for 40 seconds, in addition to causing largely a waste of film and effort, occasionally resulted in a fussing or crying response on the part of the child, which made the response unusable. Four satisfactory records for the longer period which had been obtained at 20 weeks, and two at 28 weeks, have been retained in the data used; where the additional time has been a factor in the results obtained, the fact is indicated.

It is difficult to form an idea, without actual observation, of the amount of varied behavior which a normal infant will show during such short time intervals as these. Even at 20 weeks, where the approach to the pellet is just beginning to enter into the picture, one of our reactors during the first 10 seconds made four approaches, with six shifts of regard, and made four more approaches during 10 seconds in the near position. A 44-weeks-old reactor made 15 approaches, contacting the pellet 13 times, closing his hand to grasp it 11 times, and securing it 5 times, all within less than 30 seconds.

Our records indicate that the time allowed is ample to secure a satisfactory and characteristic response to the situation. The promptness and vigor of the majority of the reactions obtained furnish evidence that the motivation involved, whatever its fundamental nature at the various age levels, was sufficient in degree to call forth approximately the best response that the reactor was capable of making.

Records of Responses

The motion picture records of the different responses have furnished the material for practically the entire analysis. The cameras used were the Bell and Howell "Filmo" type, using 16-mm. film. The photographing was carried on through an opening in the line of the camera track in the front median plane, the camera being pointed downward toward the child on a line forming an angle of 20° with the platform of the crib at the center of the dome. Supplementary records were made of a few responses at the different age levels from a position at right angles to that just described, with the camera pointed horizontally at the level of the child's head.

During the entire examination the examiner carries on a running dictation descriptive of the infant's responses, which is taken down by a stenographer outside the dome. Because of the length of time in which the child has been adjusting to this talking before the pellet is introduced, it was felt that its sudden cessation would be more likely to operate as a distraction than the dictation itself, and it was retained as part of the experimental procedure. These dictated records have in certain cases been of assistance in clarifying details not clearly shown in the film.

In addition, independent notes were made by the experimenter on most of the cases, from an observation point outside the dome. These have been found, however, to add little or nothing to the data as gathered from the other types of records. The motion pictures alone, in almost every case, furnish all the data needed for analysis of the response.

Methods of Studying the Data

The analysis of the material was carried on through a study of the cinematic records, both in motion and frame-by-frame projection—that is, through the stilling of successive frames. The apparatus utilized for this purpose was the projection table described by Halverson (13*b*), in which a standard hand-crank projector is arranged in such a way as to project its image from below on a ground-glass screen set into the table top. The device permits an observer seated before the table to operate the projector at any speed desired for studying a given item of behavior or to still any single frame for studying at length. The projector has been modified to permit the film to be run either forward or backward, making it a convenient matter to go over a single episode, or any part of it, as many times as may be necessary to gather the desired data.

An adaptation of the method described by Halverson (14, p. 131) was used for reducing the significant phases of the reactor's response to chart form in terms of time and space. Several different forms were used to record different aspects of the behavior. Form A, designed to record the total response, in its essential items, is a chart on coordinate paper, each ordinate representing a single phase of the response which it is desired to record in temporal terms. Time is plotted on the vertical scale, each interval between two consecutive abscissae representing one second. When a given item appears in the response, say closure of the hand to obtain the pellet, a line is drawn on the ordinate from

the point indicating the time of the beginning of the movement up to the moment of its completion. The items so charted on Form A are: *regard*, for the presentation of the pellet, for the pellet itself, for the reactor's own hand, for the examiner, and for the general environment ("looking around"); *activity* (approach and withdrawal) of the right hand and of the left; *contact* with the pellet; *closure* of the hand on the pellet; *holding* the pellet; carrying it, dragging it, or pushing it. A wide column on the right is used for descriptive annotations, including details as to the type of approach, grasp, postural changes, etc.

Form B contains a figure representing the part of the table surface nearest the reactor, drawn to scale, including such of the guide-lines as are most helpful in orientation. On this figure (similar to those illustrated in Halverson's monograph, p. 175) may be plotted the route of an approach to the pellet. Below this figure, on a straight line representing the table surface in cross-section view, is drawn the *vertical profile* of the approach, showing the distance of the hand above the table top throughout its advance. The point of reference for charting in each case is the tip of the index finger of the approaching hand; the position throughout the approach is obtained by stilling the successive frames and plotting the position in each one.

Other forms are used for more detailed analysis of specific parts of the behavior, and are designed to permit of entering the significant details of the response as shown by all the individual members of a group on

a single page. In the present study, for example, Form C was used for a detailed analysis of the initial approach, and Form D for the first successful prehension of the pellet.

The time measures are obtained by counting the clicks of the shutter on the projector as it exposes successive frames. The cameras have been carefully adjusted to give an initial speed of slightly more than 16 frames a second, which decreases slightly at a uniform rate as the camera continues to run. Timing during the 40th second of operation, which represents the end of our longest episodes, has shown the number of exposures during that second to be, in the case of none of the cameras, fewer than 15.5. Thus, by counting each click of the shutter as marking off 1/16 second, the maximum time error is 1/32 second, which is quite accurate enough for the type of behavior studied.

The method of procedure in analyzing a photographed episode is as follows: The episode is run off once or twice at normal speed to obtain a clear idea of the nature of the total response. It is then run through slowly to obtain details as to the direction of the reactor's regard throughout the episode for the different objects specified on the form. The projector is run at a moderate rate of speed, the clicks of the shutter being counted, until the first shift of regard occurs, when the film is stopped, and the line representing the duration of the first regard is drawn on the appropriate ordinate. This is continued for each successive regard. The episode is then run through again in the same way to chart the responses

of the right hand relative to the pellet, and again for the left hand, approach movements being charted as straight lines; withdrawal, or activity preliminary to an approach, by waved lines. The instant of establishing contact with the pellet is marked by a short horizontal dash in the "contact" column, while the items of closure, grasp, etc., are indicated by straight time lines. Another slow and interrupted running through of the entire episode permits the descriptive data to be entered on the record, in as much detail as necessary.

Items of the response which are to be studied individually are made the subject of a frame-by-frame analysis. The diagrams of approach, already mentioned, and the analysis of specific approaches and grasps are made in this way. When the analysis is completed, the entire response, in its significant details, has been reduced to a series of charts and tables, in a form which permits of making any desired comparison with the responses of other reactors.

IV

RESULTS OF THE EXPERIMENT

A complete act of visual-motor prehension is made up of three essential parts: (1) the visual perception of the object—the *regard;* (2) the directing of the hand toward the object to establish contact—the *approach;* (3) the closing of the hand on the object—the *grasp,* or *closure.* This division has been used as the basis for the analysis of the data obtained in the present experiment.

The Analysis of Regard

All the reactors, with the exception of a single case at 20 weeks, definitely regarded the pellet. This means 90% of cases at 20 weeks, and 100% at all other ages. These figures are at variance with the earlier findings of Gesell (10, p. 104) and even more with those of Linfert and Hierholzer (19). Gesell assigned success on this test a B+ rating at 6 months, on the basis of its having been passed by between 50 and 65% of the 50 cases studied. Linfert and Hierholzer found it to be passed by only 36% of infants at 6 months. The size of the pellet which they used is not reported, but it is extremely unlikely to have been smaller than the one used in this experiment.

Three probable reasons suggested themselves for the differences between the results obtained here and those of the two investigations cited: (1) The cinema records probably show a number of transient regards for the pellet which would be overlooked in trying to

observe the original response alone. (2) The procedure in both the cases mentioned included using every possible means of drawing attention to the pellet, such as moving it about on the table, lifting it up and replacing it, tapping near it with the finger, etc. It seems likely that these methods would have the result of distracting the infant's attention from the pellet rather than the desired result of calling attention to the small test-object. (3) The simplified conditions under which the pellet was presented in the present experiment reduce the number of possible distractions and make the pellet a relatively more conspicuous object.

As a matter of fact, preliminary investigation by other members of the Clinic staff, based on dictated records of the responses of 16-weeks children to the pellet, presented under conditions similar to those herein described, indicate that even at that age definite regard is found in from 40 to 50% of cases. Thus the balance of probability favors the explanation in terms of the conditions of presentation. No other investigators than those named have reported data on the regard for an object of comparable size to the pellet.

At all ages except 20 weeks the pellet was regarded more frequently, and for a longer period of total time, than any other object of the four charted—the pellet, the infant's own hands, the examiner, and the general environment. At 20 weeks the environment received slightly more attention than any other object—that is, there was more looking around at that age, while the pellet and the examiner received an approximately equal amount of attention.

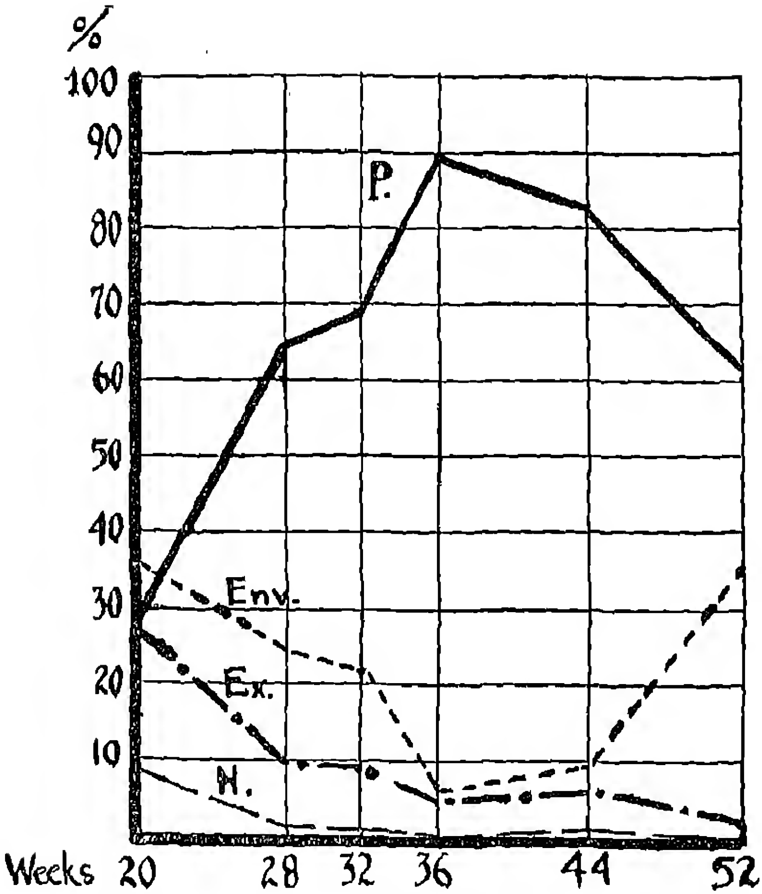

FIGURE 1

PERCENTAGE OF TOTAL AMOUNT OF REGARD DIRECTED TOWARD PELLET (*P*), THE ENVIRONMENT (*Env.*), THE EXAMINER (*Ex.*), AND THE REACTOR'S HANDS (*H*)

Figure 1 presents in graphic form the percentage of the total amount of regard, in terms of time, for these

four objects at all ages.[3] It will be seen that the relative amount of time of regard for the pellet shows a sharply rising curve up through 36 weeks, with a slight drop at 44 weeks, and a sharper drop at 52. This drop in the highest age groups is due in the main to the increased efficiency in grasping, which results in a shorter period of regard before the pellet is secured, and to the increasing tendency (especially marked at 52 weeks) to transfer the gaze from the pellet immediately after it is secured as it is being carried to the mouth.

The examiner's presence evidently does not have as much of a distracting effect as might have been feared. After 20 weeks she receives relatively little attention, most of it going to the pellet, with the environment a low second. After 36 weeks she gets no attention at all until after the pellet has been secured.

The nature of the regard for the reactor's own hand is of especial interest in view of the prominent rôle which it presumably plays in the early development of visual grasping. The hand is at all ages the least regarded of any of the four objects, both in the number of times it is regarded and in the amount of regard it receives, and it receives an almost negligible amount of attention after 28 weeks. Reaching zero at 36 weeks, there is a slight reappearance at 44, at which age, for

[3]The number and length of the tables constructed in the course of this experiment for the purpose of organizing data make it impracticable to publish here more than a few of especial importance. The original data are on file, and will be available for examination by any interested person at any time.

reasons that will be discussed later, there is occasionally a little greater difficulty in securing the pellet than at 36 weeks; as prehension is rapidly perfected after this time, regard for the hand again passes out of the picture.

Because of the hypothetical importance of the visual associations being formed between hand and object at the early age levels, it is of interest here to analyze the shifts of regard between the hand and the pellet. This is done in Table 3.

TABLE 3
SHIFTS OF REGARD BETWEEN HAND AND PELLET, FOR ALL CASES

Age group / Shifts of regard	20	28	32	36	44	52
Pellet to hand	3	0	1	0	0	0
Hand to pellet	1	0	0	0	1	0
Pellet to hand to pellet	4	4	0	0	2	0
Hand to pellet to hand	0	0	0	0	0	0
Hand, neither followed nor preceded by pellet	12	2	2	0	0	0
Total	20	6	3	0	3	0

The 20-weeks infant looks frequently at his hands without apparent association with the object; but in a good proportion of cases regard for the hand immediately follows regard for the pellet, and in slightly more than half these cases attention returns to the pellet as the next object after the hand has been fixated. This shifting of regard from pellet to hand to pellet comes out even more prominently at 28 weeks, where, however, the hand is less often fixated than at the earlier age. Attention, as would be expected, seldom goes from the hand to the pellet unless the pellet has been the last previous object of regard.

Types of Regard for the Pellet. A distribution of all the separate regards for the pellet occurring at the various age levels, in terms of their duration, reveals a striking characteristic of this response at the earlier ages (Table 4). Clearly marked at 20 and 28 weeks, and almost as clearly at 32, is a tendency for the individual regard to fall within one of three definite and separated time divisions. This tendency permits us to speak of three types of regard, as far as these ages are concerned—*transient* regard, *brief* regard, and *prolonged* regard.

At 20 weeks, about three-fourths of all regards are of the transient variety, lasting for 1½ seconds or less, and there is a full second between the upper limit of this group and the lower limit of the next higher group, in which the duration is from 2½ to 5 seconds. In addition to these two groups there is an occasional regard which lasts somewhat longer—two, in the 28-weeks infants represented here, both of more than 6½ seconds.

At 28 weeks the upper limit for transient regard, as well as both the upper and lower limits for brief regard, are ½ second above those of the youngest group. At 32 weeks the total number of regards is smaller, and the median duration somewhat longer; the three groups appear, however, within approximately the same limits as before. Above 32 weeks the wider distribution of time intervals, and the increasing effect of other factors of the total response upon the duration of regard, render less serviceable the differentiation upon the basis of these three types.

TABLE 4

DURATION OF ALL REGARDS FOR THE PELLET

Age in weeks Time in seconds	20	28	32	36	44	52
1/16- ½	20	3	1	1		
9/16- 1	12	2	2		1	1
1 1/16- 1½	4	5	1	1	1	2
1 9/16- 2		6	1	1	1	2
2 1/16- 2½			1			2
2 9/16- 3	3			1	2	2
3 1/16- 3½	1	4	5			2
3 9/16- 4	2	2		1	2	1
4 1/16- 4½	2	1	2	1	2	2
4 9/16- 5	1	1		1		1
5 1/16- 5½		2			1	
5 9/16- 6			1	1		
6 1/16- 6½			1	1	1	
6 9/16- 7	1					1
7 1/16- 7½			1			
7 9/16- 8					1	
8 1/16- 8½						
8 9/16- 9				1	1	
9 1/16- 9½	1	1			1	
9 9/16-10						1
10 1/16-10½						1
10 9/16-11				1	1	
11 1/16-11½						
11 9/16-12				1	1	
12 1/16-12½						
12 9/16-13				1		
13 1/16-13½						
13 9/16-14					1	
14 1/16-14½						
14 9/16-15						
15 1/16-15½			1		1	
15 9/16-16						
16 1/16-16½			1			
16 9/16-17						
17 1/16+				1	2	
Total	47	27	18	14	20	18

TABLE 5

MEDIAN DURATION OF ALL REGARDS FOR THE PELLET AT ALL AGES

Weeks	Median	*M.V.*
20	.68	1.12
28	1.83	1.62
32	3.35	2.74
36	5.25	3.89
44	5.75	4.70
52	3.13	1.87

TABLE 6
THE THREE TYPES OF REGARD
MEDIAN DURATION AT 20, 28, AND 32 WEEKS

Weeks	Transient regard	Brief regard	Prolonged regard
20	.46	3.75	8.0
28	1.35	3.88	9.25
32	1.25	5.25	15.75

Transient regard is the prevailing type at 20 weeks, and in a lesser degree at 28 weeks. It seldom initiates an approach toward the pellet, or an increase in activity of the arms and hands. It may occur in the form of an interruption as the gaze crosses the line of the pellet in passing along the table top; or it may take place with a directness which suggests that it is being directed toward the pellet as a result of previous stimulation by the same object. At 20 weeks most of the initial regards for the pellet, and at 28 weeks about half, are of the transient variety, suggesting perseveration of regard which has first been stimulated by the larger, moving object, the examiner's hand holding the pellet.

At 32 weeks and above, transient regard, when it appears, is usually given to the pellet after it is secured, while held in the hand, or after unsuccessful attempts to secure it have brought about a cessation of activity directed toward prehension.

Brief regard, lasting from 2½ to about 6 seconds, covers the range in which fall the medians for all groups above 28 weeks (see Table 5). In almost every case where it is directed toward the pellet lying on the table top it is accompanied by attempts at prehension,

and in the case of the older infants it usually persists until the pellet has been secured. Occasionally at 20 weeks it may take the form of a more or less passive stare, but this is not characteristic of the group as a whole, and almost never occurs above this age.

Prolonged regard is most likely to occur in conjunction with repeated efforts to secure the pellet, or with the exploitation of it in play which occurs at some of

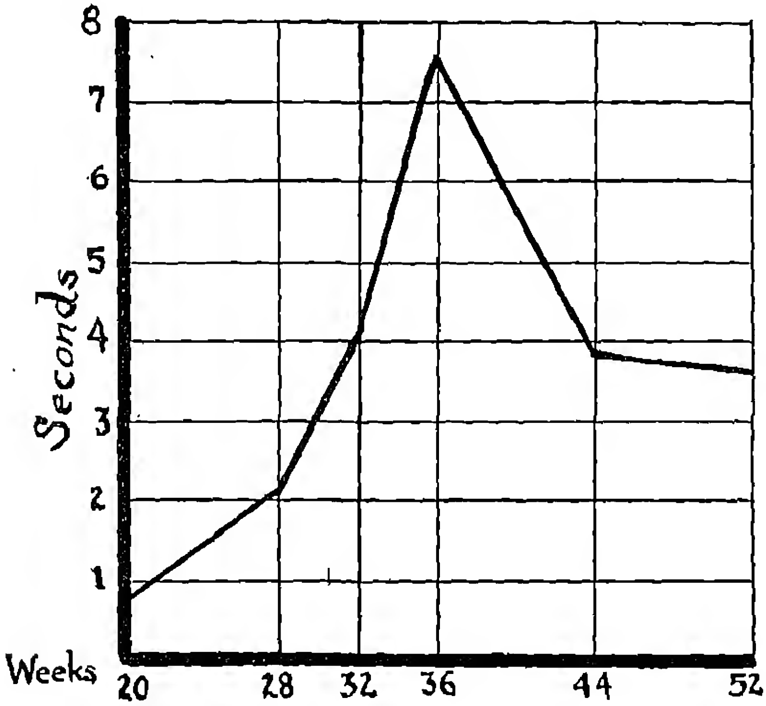

FIGURE 2
DURATION OF INITIAL REGARD FOR THE PELLET
(Median values for each age)

the older ages. It may occasionally partake of the passive staring quality already mentioned at 20 weeks, but a long regard so seldom occurs at this age that it must be considered an atypical response.

The *initial regard* for the pellet, the first regard following the presentation, is the one for which conditions are most comparable for all cases. The median values for this regard at the different age levels are charted in Figure 2. The curve rises sharply, with marked acceleration, from 20 through 36 weeks. The drop at 44 weeks is associated with the increased difficulty in securing the pellet, which has been mentioned earlier. The hand closes on the pellet and is drawn back without having grasped it; the regard follows the hand, as though successful prehension had actually taken place, and only after the discovery that the pellet has not been obtained does it return to the test-object. At 52 weeks a short initial regard usually ends in successful prehension and quick disposal by carrying the pellet to the mouth.

On Figure 3 are charted the values for the average of the longest, the shortest, and the median regards, for all cases at each age. In general, the curves for these values show approximately the same form that is taken by the curve for initial regard, the most marked difference being the rise shown for the average of the longest regards at 44 weeks. The drop at 52 weeks has been accounted for above.

Summary of the Development of Regard. The process of development which takes place in connection with regard for the pellet during the age range covered

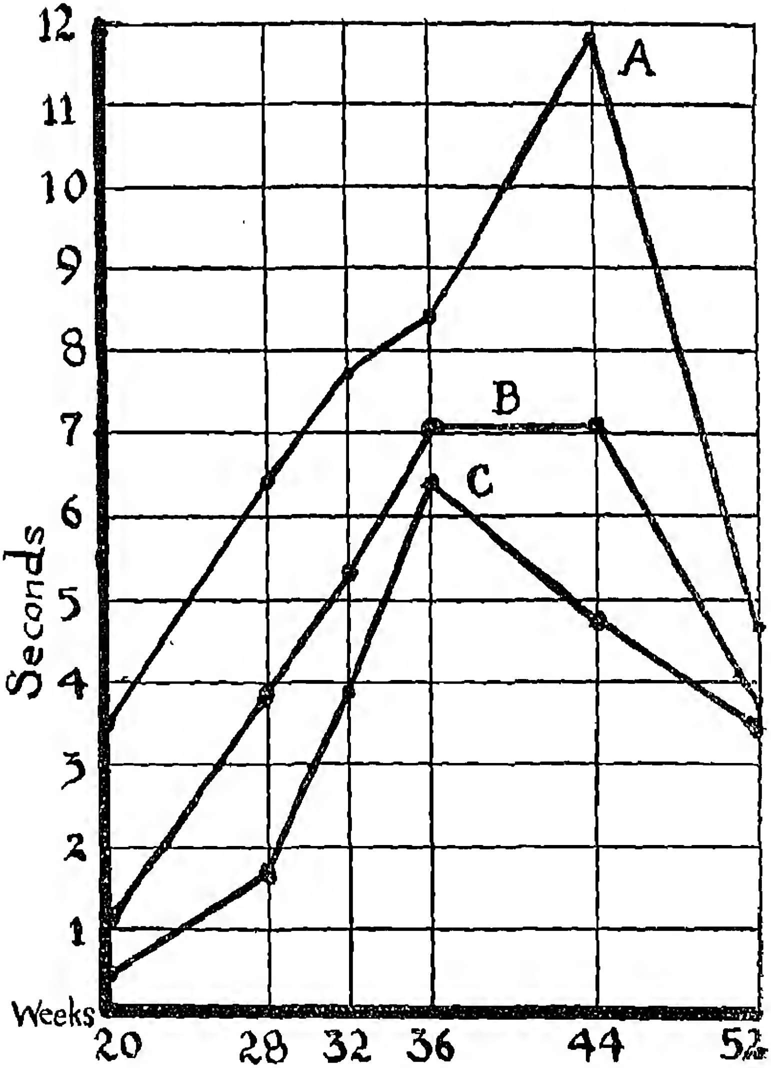

FIGURE 3
AVERAGE LONGEST (*A*), MEDIAN (*B*), AND SHORTEST (*C*) REGARD FOR PELLET FOR ALL CASES AT EACH AGE

by this study, and under the conditions here established, is manifested chiefly in three ways:

1. Through a relative increase in the number of regards for the pellet and in the amount of time it is regarded, as compared with other objects of attention. This shows a definite increase from 20 weeks through 44 weeks.

2. Through an increase in length of the individual regards. This also reaches its peak at 44 weeks.

3. Through an increase in the number of regards accompanied by activity directed toward securing the pellet. This advance takes place mainly between the ages of 20 and 28 weeks. After 28 weeks, practically all regards up to the time of successful prehension are accompanied by one or more approaches.

The characteristic attentional response at 20 weeks, following the presentation of the pellet, is a transient regard for the stimulus object, succeeded by a relatively large number of shifts of attention, in the course of which the pellet is again regarded one or more times. Most of these regards last less than 1½ seconds, and are unaccompanied by any effort to secure the pellet. A few, occurring in the case of about half the reactors at this age, last for from 2½ to 5 seconds, usually with some attempt at prehension. Regard of longer duration occurred only twice in this group; in one case it was accompanied by a number of abortive approaches to the pellet, and in the other by no definite prehensory movements.

At 28 weeks the total number of regards is fewer, and the individual regards tend to be longer. Tran-

sient regard is still more frequent than either brief or prolonged regard, but is likely to last from 1 to 2 seconds and to be accompanied by one or more longer regards. Passive regard, without attempt at prehension, has almost disappeared by this age.

From 32 to 44 weeks the increase in duration of regard continues, along with increasing intensity of the efforts to secure the pellet. By 44 weeks, the first of the age levels studied at which all reactors achieved successful prehension, the median duration of regard has risen to 5¾ seconds, while the median length of the longest regard for all cases was nearly 12 seconds. There is a greater degree of variation in the length of regard at this age than at any other, corresponding with the greater variability shown throughout the entire response.

Between 44 and 52 weeks the several parts of the act of prehension develop into one smooth and efficient response. Nearly all reactors at 52 weeks secure the pellet within two or three seconds, and inspect it only briefly before carrying it to the mouth. Thus the total number of regards at this age, and the average duration of regard, both show a falling off from the 44-weeks figures. Regard can no longer be considered as significant in itself, aside from its relationship to the total response.

Regard for other objects than the pellet also shows growth changes. The greatest attention for the human factor in the situation—the examiner—occurs at 20 weeks, and shows a marked drop thereafter. At 20 and 28 weeks there is occasional tendency for the gaze

to shift between the infant's own hands and the pellet. The recurrence of this response at 44 weeks is in a form which suggests that it is a different type of response than in the cases seen at the earlier ages.

The Development of Approach

By an *approach* to the pellet is meant any movement of the arm in the direction of the pellet, accompanied by regard for it, which, because of the quality of regard or the definiteness of the movement, seems to be directed toward establishing contact with it. Actual contact need not take place for a response to be classified as an approach; in this way the use of the term here differs from "reaching," as used by Jones (16) and others to include only such approaches as result in successful prehension. To avoid some possible confusion in comparing these results with those of others, the term "closure" has also been used in preference to "grasp" for the closing of the hand in an attempt to secure the object. "Grasp" connotes success in attaining the object, and is also widely used in a sense which includes the approach itself, and is partially or entirely synonymous with "reaching."

Thus the term "approach" includes the more primitive types of groping response as well as more direct reaching. In one case, at 32 weeks, the approach was apparently stimulated by contact alone; in all other cases it was initiated by regard.

Halverson (14) distinguishes three types of approach which he has described as "(1) the *backhand approach,* in which the hand sweeps outward and for-

ward toward the cube in curvilinear manner, with the ulnar edge of the hand leading, (2) the *circuitous approach,* in which the hand in advancing moves outward laterally during the first part of the approach and inward toward the midline of the table during the latter part, thus describing an arc, and (3) the *straight approach* . . . (in which) the path of the forefinger, as seen from above, approximates a straight line." He points out that in passing from the lower to the higher levels of age, the path of approach shows an increasing directness, so that the backhand and circuitous approaches of the younger infants resolve into the straight approach of the older ones.

This classification is adequate, and emphasizes the most significant phase of behavior growth manifested in the development of approach—the increasing economy of movement as the infant grows older. The backhand approach does not represent a distinct type on the same basis as the other two. It may be either circuitous or straight, and it occurs only when the hand starts from a position across the line in which the pellet is located, or when its initial position is one in which the radial side of the hand is nearest the table edge and approximately parallel with it.[4]

The response may be classified also in terms of its vertical profile (see p. 148). On this basis Halver-

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[4]"We might have adopted the plan of starting all situations by placing the infant's hands at predetermined points on the table or at his sides, were we certain that such demands on the infant would not interfere with or hamper his characteristic reactions"—Halverson (14). For the same reason no such procedure was used in presenting the pellet.

son distinguishes the *loop approach,* the *planing approach,* and the *slide approach.* The slide approach is one in which the hand moves forward on the table top during the advance. In the other two types, the hand is raised above the table. A planing approach is one in which the downward movement toward the pellet starts from a relatively early point in the approach; the hand as it comes down to the table at the end is still moving forward. In the loop approach the direct downward movement toward the pellet does not begin until the hand is relatively close to it, so that the vertical profile shows a distinct drop at the end.

The criteria for the planing and loop approaches tend to overlap, but a satisfactory differentiation may usually be made.

The results of the present experiment do not suggest the need for creating new categories of approach, and Halverson's terms have been retained here. Occasional responses are atypical and resist classification in these terms,[5] but these are so rarely met with that it is convenient to describe the behavior rather than to multiply categories.

Approach and Contact. The number of approaches at each age is analyzed in Table 7, together with the number which result in actually establishing contact with the pellet. The efficiency of approach in this respect is seen to rise very rapidly during the period

[5]One reactor at 52 weeks, for example, uses a sort of hand-crawl. The hand literally crawls forward on the fingers, with a slight rocking movement from side to side. The hand remains in contact with the table throughout, but does not slide.

from 20 through 32 weeks, from which time only one or two approaches at each age level fail to result in contact.

TABLE 7

APPROACH AND CONTACT AT ALL AGES

Age in weeks	20	28	32	36	44	52
No. of reactors approaching pellet	6	9	10	10	10	10
Percentage of reactors approaching	60	100	100	100	100	100
Total no. of approaches	20	66	30	31	68	15
Average no. of approaches	2	7.4	3	3.1	6.8	1.5
Percentage of reactors approaching with contact	30	100	100	100	100	100
Total no. of approaches with contact	3	38	28	30	66	14
Average no. of approaches with contact	.3	4.2	2.8	3.0	6.6	1.4

The greatest difficulty is encountered by the reactors at 20 weeks. Only 60% of these approach the pellet at all, while only half of those who do approach succeed in touching it. Two of the three contacts at this age occurred with the pellet in the near median position. There were no cases of successful prehension.

The failure to establish contact may be due (*a*) to misjudgment of the distance, or (*b*) to failure to coördinate the movements of the different muscle-groups involved.

An example of failure through faulty coordination is found in the case of a 20-weeks reactor who made a number of abortive approaches to the pellet. In one of these the left hand started its approach from a position in which it was drawn back and to the left, with the hand raised about 8 inches above the table surface, so that the establishment of contact with the pellet would require simultaneous or successive flexion from the shoulder and from the elbow (the pellet is in the

near position, 3 inches from the table edge) and a lowering of the whole arm from the shoulder. In the second frame of the approach sequence the hand and arm have begun to be lowered, but the third frame shows that instead of flexing, the forearm has begun to extend, carrying the hand farther from its objective rather than nearer. Frames 4 and 5 show completion of the movement in this way to the table surface, with the hand in a plane 1 or 2 inches farther from the pellet than at the beginning. The entire approach is completed in the five successive frames—that is, in 5/16 of a second.

Misjudgment of distance is about equally important at 20 weeks with faulty coordination. Most approaches fall short of the pellet by distances of from ½ inch to 6 or 8 inches. These longer distances usually result from failure to coordinate, as in the example cited, but are sometimes due simply to an unexplained inhibition of the response after it has begun.

Adjustment to complete a response that has overshot or undershot its mark is not found at 20 weeks. The attempt to approach is in such cases either abandoned temporarily or permanently, or the hand is drawn well back for a second approach.

At 28 weeks inability to coordinate the movements properly does not play a large part. Infants at this age seem able to complete a response from almost any starting position. The speed with which the approaches are made is probably the greatest factor in causing misjudgment of distance. As in the case of 20-weeks infants, the failure to establish contact usually

leads to a new start rather than to an adjustment of the hand to complete the distance. Slightly more than half the 28-weeks approaches are successful in contacting the pellet. In only one case was there successful prehension, although 5 of the 9 reactors closed on the pellet.

Failure to contact, in the very few instances in which it occurs above 28 weeks, has very often a deliberative quality; as the hand approaches there is a pause, followed by a slight readjustment of the hand and a new approach in a manner permitting better grasping. Failure never has the aspect of being due to faulty muscular coordination, although even at 36 and 44 weeks it may be the result of too precipitous an approach.

Directness of Approach. The first approach has been singled out for special consideration because it is the one for which conditions are most nearly similar for all cases. The outstanding uncontrolled factor affecting the form of this approach is the initial position of the reactor's hands, which, for reasons already stated, was not predetermined. This factor is itself, however, to some extent a function of behavior growth as well as physical growth. The infants up through the age of 36 weeks tend to hold the hands near the table edge, or drawn in against the body, as observed also by Halverson. At 44, and especially at 52 weeks, one or both hands usually is extended well forward on the table.

We measure the directness of approach in terms of two values: (1) the maximum distance by which the

path of approach diverges from a straight line; (2) the maximum height of the approach.

The first value is obtained from the chart showing the route of approach, by drawing a straight line from the starting position to the position of the pellet; the amount of maximum divergence is the greatest perpendicular distance from this line to the curve of approach. The maximum height of approach is shown directly on the vertical profile.

The average values for these two items are charted in Figure 4. The curve representing maximum height

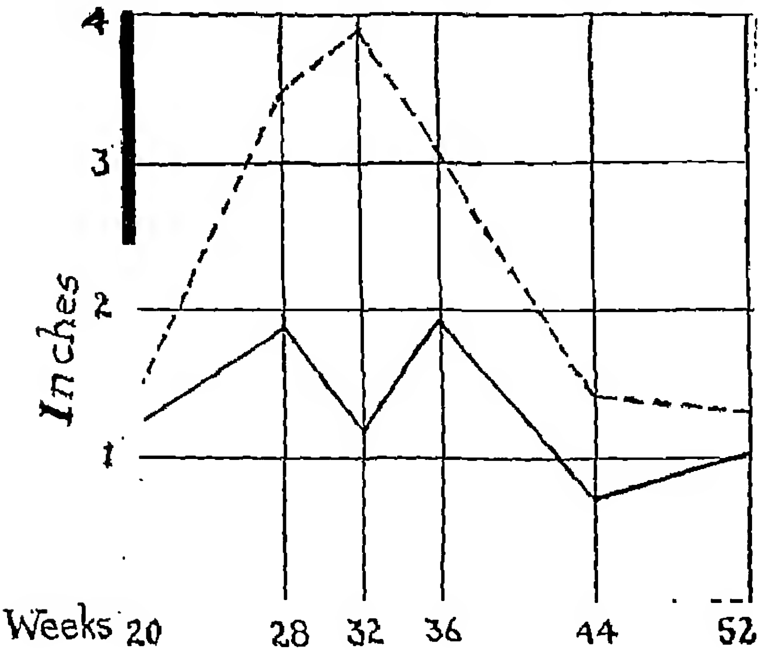

FIGURE 4
DIRECTNESS OF APPROACH
- - - - Maximum height of initial approach (average)
———— Maximum divergence of initial approach from a straight line (average)

shows the most definite gradation during the age range studied, reaching its highest point between the ages of 28 and 36 weeks, and dropping sharply at 44 weeks. One reason for the low 20-weeks figure is perhaps the relative lack of muscular strength at that age.

The curve for the average divergence from a straight line also shows a dropping off toward the upper age levels, representing a straightening out of the approach. The drop at 32 weeks is probably accounted for by certain characteristics of the total approach at that age. A large number of quick slapping or raking approaches occurs among these children, starting with the hand held high (the average maximum height is highest in this group) and descending sharply in almost a straight line, to the table, near the pellet. At this age also, in some cases, the hand starts from a position farther to the side than at most other ages, and is brought forward and outward toward the pellet extended almost to full length. The larger arc that it thus describes comes closer to a straight line than would otherwise be the case.

Starting-Time and Duration of Initial Approach. These values are given in Table 8.

TABLE 8

STARTING-TIME AND DURATION OF INITIAL APPROACH

Age in weeks	20	28	32	36	44	52
Average time from end of presentation to initial approach, in seconds	2.6	—.45	.65	—1.22	1.07	.5
Average duration of initial approach	.73	.98	.94	1.35	1.40	1.33

At 20 weeks, approach is a much less characteristic part of the total response than at any higher age level, and is thus slower in appearing after the pellet has been presented. When it does appear it is of a very rapid and, as we have seen, poorly controlled sort. By 28 weeks approach is so definitely established that the child tends to anticipate the placing of the object, and reaches for it before it has left the examiner's hand. This tendency is even more strongly marked at 36 weeks, where the approach is usually begun almost as soon as the examiner's hand begins to move forward. The 44-weeks reactors regard the pellet longer before beginning to reach for it than any other group above the age at which approach becomes universal.

The types of approach in terms of the vertical profile are listed in Table 9. The dominance of the loop approach at the period from 28 through 36 weeks begins to disappear at the latter age, and is followed by an increase in the number of planing and sliding approaches and their combinations. The planing type may be said to be in general the most efficient and direct of all these types, except in cases where the dis-

TABLE 9

Types of Approach in Terms of the Vertical Profile, Based on the Initial Approach of All Cases

Age in weeks	20	28	32	36	44	52
Slide	2	0	1	0	1	2
Plane	1	1	1	2	4	2
Loop	1	7	8	4	2	3
Combined loop-slide	2	1	1	1	1	0
Combined plane-slide	0	0	0	3	1	2
Other forms	0	0	0	0	0	1

tance of approach is so short that the hand can be easily and quickly slid over the object.

Bilateral Approach. Bilateral approach is commonest at 20 weeks, where 4 of the 6 initial approaches are of this type. There are two each at 28 and 32 weeks, and one each at 36 and 44. Three types of bilateral approach may be differentiated: (1) simultaneous, (2) successive, and (3) partial. In the simultaneous bilateral approach, both hands are in forward motion at the same time. In the successive bilateral type the second hand starts as the first hand ends its approach. A partial bilateral approach is one in which the approach of one of the hands is inhibited part way to the object while the other continues. Simultaneous bilateral approach, the most common at 20 weeks, tends to be supplanted by the partial bilateral and then the successive bilateral as age increases.

Summary. The development of approach to the pellet shows the following changes taking place:

1. Increased accuracy in making contact with the object, occurring between 20 and 28 weeks, from which latter age practically every approach leads to contact.
2. Increasing directness of approach from the starting position to the object, shown by (*a*) a lowering of the average vertical height of the approach, (*b*) increasing tendency of the path of approach to approximate a straight line, and (*c*) a change in the characteristic form of approach, from the loop to the planing type.
3. A gradual but definite increase in the duration of the approach, accompanying an increase in efficiency.

FIGURE 5 FIGURE 6 FIGURE 7

Figure 5: 28 Weeks—Circuitous Plane-Slide Approach (The pellet has been displaced from the standard position.)
Figure 6: 32 Weeks—Circulation Loop Approach
Figure 7: 36 Weeks—Circuitous Planing Approach

Figures 5 to 8, inclusive, illustrate successive stages of characteristic approaches at various ages. These pictures bring out many of the points that have been discussed as showing the behavior growth in this particular phase of prehension. Figures 6 and 8, each illustrating a loop approach, but with an interval of 12 weeks between the ages represented, show the striking increase of control that takes place in the response during that relatively short length of time.

The Development of Grasp

By the term "closure" is meant, in this discussion, the closing of the hand, or the flexing of the individual digits, in such a manner that if the movements are sufficiently well coordinated the stimulus-object will be secured. "Closure" is preferred for the general term; "grasp" will be used more specifically to refer to successful prehension.

The number of closures and the number resulting in successful prehension at the several age levels are given in Table 10.

TABLE 10
Closure and Successful Prehension

Age in weeks	20	28	32	36	44	52
No. of reactors closing	1	5	10	10	10	10
Percentage of reactors closing	10	56	100	100	100	100
No. of reactors securing	0	1	7	8	10	10
Percentage of reactors securing	0	11	70	80	100	100
Total no. of closures	1	29	36	21	48	14
Average no. of closures	.1	3.2	3.6	2.1	4.8	1.4
Total number of successful grasps	0	1	13	9	26	12
Average no. of successful grasps	0	.11	1.3	.9	2.6	1.2

In comparing these figures with those which have been given for the other phases of prehension, it will

be seen that the ability to secure the pellet, under the conditions of this experiment, is the last stage to be perfected. It does not appear in all the cases of any one group until 44 weeks; and firm holding of the grasped object is not characteristic of any but the 52-weeks group.

The Types of Grasp. Halverson (14) has distinguished 10 types of grasp when the stimulus object is a 1-inch cube. The number of major types involved in the development of fine prehension appears much smaller. This is probably due in the greater part to the difference in the size of the objects; there are fewer ways to which a very small object can be grasped than in the case of an object the size of the cube. It is probable, too, that the relatively advanced age at which definite prehensory response to the pellet takes place with any frequency tends to eliminate some of the more primitive forms which he found.

The types of closure shown by the reactors in the present experiment are as follows, in the genetic order in which they occur:

1. *Whole-hand closure,* in which the prone hand is brought to a closed fist by simultaneous flexion of the fingers, with the thumb lying alongside the flexed forefinger. This is the most primitive type of closure, occurring in the only closing response found in the 20-weeks group. It is not characteristic at any of the higher age levels, but occurs at times even as high as 44 weeks, after repeated failure to secure the pellet has led to a regression to more primitive forms of response. In none of the cases studied here did it occur

in a form sufficiently well coordinated to lead to successful prehension, but in cases outside the experimental group it has sometimes been observed to do so.

2. *Palmar prehension,* in which the fingers flex under in such a way as to drag the pellet against the heel of the palm, where it may be held. This is a more deliberate and better coordinated form of whole-hand closure, with some degree of finger-selection. In practically all the cases seen, the radial digits, with the exception of the thumb, are those in contact with the pellet. In the more primitive forms there is simultaneous flexion of the fingers; but from 36 weeks there is an increasing tendency for the 3d, 4th, and 5th fingers to be flexed under at the start, leaving the forefinger extended to drag the pellet back. The more this is the case, the more likely the pellet is to be secured by this form of closure.

3. *Scissors closure.* This name has been assigned to a type of closure in which the thumb is drawn in against the side of the flexing forefinger in a manner somewhat similar to the action of these digits in operating a pair of scissors. In this type of closure, occurring principally from 36 to 44 weeks, and in a few cases at 52 weeks, the pellet tends to be secured between the thumb and the radial side of the forefinger; properly coordinated, it is quite efficient in securing the pellet, but does not leave it in a satisfactory position for manipulation. In its early stages it is similar to the superior type of palmar prehension, with the adduction of the thumb added. It is the first type in which the thumb plays an active part.

4. *Pincer prehension* starts from a position similar to the first position for the scissors closure, that is, with the hand supported on the knuckles or tips of the three ulnar digits, and with forefinger and thumb extended. The forefinger does not flex clear under, as in the scissors type, but draws back in such a manner that the tips of thumb and forefinger meet, allowing the pellet to be secured between them.

At 52 weeks, where this is the most characteristic type of prehension, the usual form is with the hand raised so that thumb and forefinger come together in the vertical plane. There is beginning to appear, however, a somewhat superior form of the same grasp, in which thumb and finger extend obliquely forward, with the distal phalanges, rather than the tips, resting on the table. This is the most common form seen in adults when confronted with an object about the size of the pellet--though many make use of the vertical form—and is the most efficient of all, permitting, as it does, a steadier closing in of the fingers, making a larger area of their surfaces available for contact with the object.

The pincer type of grasp appears in a few other variations, the most common being one in which the middle finger is substituted for the forefinger, and another in which the middle finger or the middle and fourth fingers together are brought up simultaneously with the forefinger as a group, thus offering a larger surface against which to press the object, and affording a firmer grasp.

The development of closure is thus seen to be

marked by an increasing dominance and differentiation of the radial digits. This begins as early as 28 weeks, when the fingers nearest the pellet at the end of an approach are in practically every case those on the radial side of the hand. The types mentioned tend to advance from one into the other by means of intermediate stages, forming a clearly marked developmental series.

As was found to be the case with approach, there are certain atypical grasping responses occasionally met with, which seem to come about accidentally for the most part, and which do not occur with frequency which warrants considering them as characteristic responses. The pellet, for example, may occasionally be secured between the second and third fingers, or between other pairs of digits, in making an adjustment of the hand which brings the fingers together. In such cases it is never retained for more than a second or two, and is then usually approached again with a more characteristic form of closure.

Table 11 lists some of the more significant aspects of the first successful prehension based on all cases giving this response at each age level. These data suggest the following conclusions:

1. The pellet is not secured as a characteristic response at any of the age levels studied below 32 weeks, and not in 100% of cases until 44 weeks.

2. There is little variation in the length of time it takes the infants, at whatever age, to secure the pellet, using any type of closure. Those of 36 weeks tend to take slightly longer than those of other ages.

3. From 32 weeks on, the pellet, if secured at all, is

TABLE II
ANALYSIS OF FIRST SUCCESSFUL PREHENSION FOR ALL CASES SECURING PELLET

Age in weeks	28	32	36	44	52
No. of reactors securing	1	7	8	10	10
Average time required to secure (from end of presentation)	2.8"	2.6"	3.3"	2.5"	2.6"
Average no. of approaches preceding	7	1.6	1.5	1.6	1.1
Average no. of closures	1	1.9	1.8	1.4	1.1
Types of successful closure:					
whole-hand	1	0	0	0	0
palmar	0	5	2	0	0
scissors	0	1	5	9	4
pincer	0	0	0	1	5
other forms	0	1	1	0	1
Average time retained	1.5"	2.2"	2.9"	2.1"	5.4"
Disposal:					
Dropped	1	7	5	9	2
Transferred to other hand	0	1	2	0	2
Held and inspected	0	2	2	3	8
Carried to mouth	0	1	2	2	6

likely to be secured on the first or second approach, and on the first or second closure.

4. The whole-hand closure is extremely unlikely to secure the pellet.

5. Palmar prehension occurs characteristically at 32 weeks, and occasionally at 36. When found at 28 weeks it is unlikely to succeed. Above 36 weeks it is not likely to be used as a preferred form of grasp.

6. The scissors type of closure begins to appear at 32 weeks, in primitive form. It is the preferred type at 36 weeks, and especially at 44, and one of the two preferred forms at 52 weeks.

7. Pincer prehension is a relatively superior form of grasp, which is not characteristic of any age below 52 weeks, although it may occur earlier.

8. Fifty-two-weeks infants tend to secure the pellet

more firmly than those at any younger age, to judge from the average length of time retained and the number of times it is dropped.

9. All reactors 32 weeks of age or younger drop the pellet after holding it a short time. Of the older infants, those of 44 weeks almost invariably drop it.

10. The tendency to hold the prehended pellet and inspect it, and the tendency to carry it to the mouth, are most strongly marked at 52 weeks.

The seemingly paradoxical fact that infants of 44 weeks are less efficient in securing the pellet firmly than are those 8 weeks younger is due in part to the fact that they tend to use a more advanced type of closure which has not by that age been sufficiently perfected. Personality factors enter in as well; the 44-weeks reactors show more excitement over the situation, as well as more interest in exploiting the pellet in play, than do those of any other age. Failure to grasp results more quickly in increased rapidity of movements, and frequently in a regression to more immature types of approach and closure than is the case with the slightly more stolid infants of 36 weeks.

Reasons for Failure to Secure Pellet. The more common reasons for failure to secure the pellet include the following:

1. Failure to approach. This explains the lack of grasping for nearly half the cases at 20 weeks, but none at any other age studied.

2. Failure to make contact with the pellet. This likewise accounts for no failures above 20 weeks.

3. Failure to close the hand for grasping. This is a significant item at 20 and 28 weeks, but not above.

4. Faulty coordination of the closure. In the case of *whole-hand closure,* this frequently takes the form of letting the pellet slip between the fingers as they are flexed under. Closure of this type is likely also to be accompanied by a premature withdrawal of the hand which draws it away from the pellet before it can be grasped. In *palmar prehension* also there is a tendency to draw the hand back a little in closing, resulting in a slight pivoting on the thumb. This imparts a circuitous movement to the index finger as it flexes, causing it, in a number of cases, especially at 36 weeks, to pass around outside the pellet without pulling it back. A similar tendency accounts for the failure of several closures of the *scissors* type, and, in some of the earlier attempts, of the *pincer.*

5. Substitution of a raking or pawing response for closure. This is most characteristic at 32 weeks, but shows a recurrence in several cases at 36 and 44, especially after repeated failures to secure or to retain the pellet. The most frequent result is dragging or knocking the pellet from the table, after which, under the conditions of the experiment, no further attempt to grasp is allowed.

Figure 9 shows the complete course of a typical scissors grasp, in the case of a 36-weeks-old infant. In (1) the index finger is extended and raised, preparatory to closure, while the thumb is extended on the table top beyond the pellet. (2) and (3) show the closure, the forefinger being flexed under, dragging the pellet, as

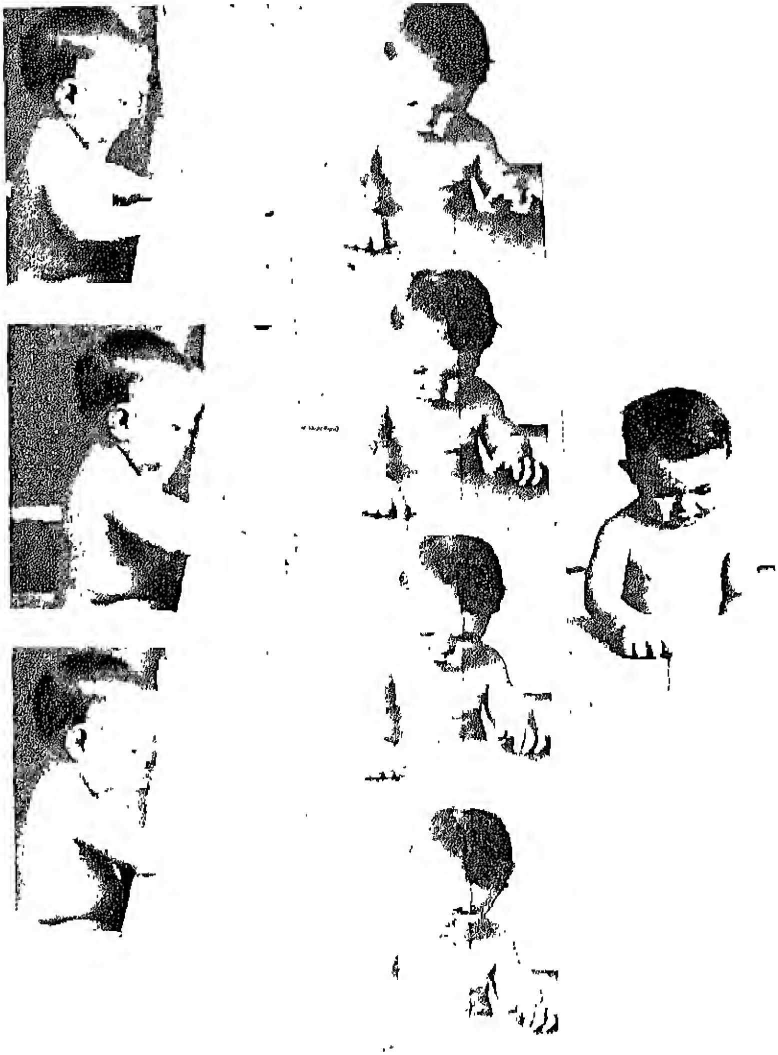

FIGURE 8 FIGURE 9 FIGURE 10

Figure 8: 44 Weeks - Straight Loop Approach
Figure 9: 36 Weeks—Scissors Prehension
Figure 10: 52 Weeks—Vertical Pincer Prehension

the thumb is drawn in against it. (4) shows the pellet, held precariously between the tip of the thumb and the side of the forefinger, being lifted and inspected. It will be observed that the cooperating activities of the non-grasping hand are in this reactor still incompletely inhibited by this age.

Figure 10 is the picture of a 52-weeks reactor securing the pellet by means of vertical pincer prehension. In comparison with the illustrations showing infants of other ages, this picture represents strikingly the degree of control, poise, and maturity, which is characteristic of infants one year of age.

V

Summary and Conclusions

The aim of the experiment is to map out the course of development of fine prehension in children under one year of age. By fine prehension is meant the ability to pick up and hold objects of small size, requiring the smooth coordination of arm, hand, and finger movements, and the cooperation of a relatively good quality of visual attention.

This ability was studied in the responses given by 59 infants between the ages of 20 weeks and 52 weeks to a white pellet, 7 mm. in diameter, which was presented under standardized conditions on a table top before which the infant was seated. Ten reactors 20 weeks of age, 9 at 28 weeks, and 10 each at 32, 36, 44, and 52 weeks, selected from average families, of Teutonic or Celtic racial stock, were used in the experiment.

The complete response of each child, up to a period of 40 seconds, was recorded in a motion picture of his behavior. These motion-picture records formed the basis of the study of the response, which was carried on by means of a motion study and frame-by-frame analysis of the individual records.

The analysis was carried on in terms of the three essential parts of an act of visual-motor prehension—*regard* for the stimulus-object, the *approach* to it, and the *closure* of the hand directed toward securing it.

The main findings may be summarized as follows:

1. The behavior growth of the infant, as repre-

sented by his ability to carry out the movements involved in fine prehension, reveals certain relatively well-defined developmental patterns in passing through the levels studied. These are shown in all three of the phases of prehension analyzed.

2. *Regard* for the pellet reflects the process of development through (*a*) a relative increase, from age to age, in the number of regards directed toward the pellet, in comparison with other objects of attention; (*b*) an increase in the duration of the individual regards; and (*c*) an increase in the number of regards accompanied by a prehensory response to the pellet.

3. Three types of regard for the pellet are distinguished on the basis of their duration: *transient regard,* lasting up to 2½ seconds, which is the characteristic type found at 20 weeks, *brief regard,* from 2½ to 6 seconds, and *prolonged regard,* lasting for more than 6 seconds.

4. Transient regard is seldom accompanied by approach or increased activity at 20 weeks, although it occasionally is so accompanied at 28 and 32 weeks.

5. Brief regard is almost always accompanied by one or more efforts at prehension. It is the type which represents the median length of regard for all ages above 20 weeks.

6. Prolonged regard usually occurs in conjunction with repeated efforts to secure the object, or with the exploitation or manipulation of it which occurs at some of the higher age levels.

7. The occurrence of these three types of regard is genetically significant from 20 weeks through 32

weeks, where the distribution of the individual regards on the basis of duration show a definite trimodal distribution which serves to distinguish them. Beyond 32 weeks this trimodality of distribution is not found.

8. The outstanding stages in the development of regard are the following, at the various levels represented in the study: *20 weeks:* The characteristic initial response is a transient regard for the pellet, followed by a large number of shifts of attention between various other objects in the environment and the pellet. Most regards for the pellet are transient and unaccompanied by approach; a few are of the brief regard type, usually with some effort at prehension. Prolonged regard seldom occurs at this age. *28 weeks:* Characterized by fewer and longer regards, although the prevailing type is still the transient. There is little passive regard, i.e., regard unaccompanied by efforts at prehension, from this age on. *32 to 44 weeks:* Duration of regard continues to increase, along with increased efforts toward securing the pellet and increasing success in obtaining it. By *52 weeks,* regard is no longer significant in itself, but has become part of a smooth, well-coordinated prehensory response.

9. Halverson's classification of approach is found to be satisfactory for the pellet situation, as for the cubes with which he worked.

10. Development of approach to the pellet is characterized by (*a*) increased accuracy in making contact with the object, rising practically to the 100% level at 32 weeks from 30% at 20 weeks, in terms of the number of reactors showing the response; (*b*) increased

directness of approach, shown by a lowering of the average vertical height of the approach, by an increasing tendency of the path of approach to approximate a straight line, and by a change in the characteristic form of approach, from the loop to the planing type; (*c*) gradual but definite increase in the duration of the approach, accompanied by increasing efficiency in obtaining the pellet.

11. The development of *closure*, or *grasping*, is marked by increasing dominance and differentiation of the radial digits. Four main types represent the main stages of maturity of this response: *whole-hand closure*, *palmar prehension*, the *scissors closure*, and the *pincer* type.

12. By the age of 52 weeks the pincer type of prehension is the prevailing one, suggesting that the maturational aspects of the development of fine prehension are beginning to reach an end, since it is a form of this grasp which is most commonly used by adults in grasping an object comparable in size with the pellet. The smoothness and efficiency of the total response at 52 weeks is also suggestive of a relatively advanced stage of maturity.

13. There is considerable difficulty in holding the pellet after it has been secured, in all age groups below 52 weeks; no infants as young as 32 weeks continue to hold it for any length of time. Of the older infants, those at 44 weeks almost invariably drop it.

14. Holding and inspecting the pellet, and carrying it to the mouth, represent the characteristic disposition at 52 weeks. Younger infants attempt the same disposal in many cases, but seldom succeed in actually getting the object into the mouth.

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LE DÉVELOPPEMENT DE LA FINE PRÉHENSION DANS L'ENFANCE

(Résumé)

Par le terme "prehension fine" on veut dire la préhension par la main des objets de grandeur relativement petite, ce qui exige une bonne coördination dans les mouvements plus délicats du bras, des mains, et des doigts, avec une bonne qualité de coöpération visuelle. On a étudié le progrès du développement de cette capacité pendant le premier an de la vie, en analysant les réponses des enfants à un petit bonbon blanc, 7 mm. en diamètre, placé sur le haut d'une table devant l'enfant assis dans des conditions standardisées. On a présenté la situation à 59 enfants, qui avaient l'âge de 20, de 28, de 32, de 36, de 44, et de 52 semaines. On a fait des photos cinématographiques des réponses, desquelles on a obtenu les données employées dans cette étude par l'analyse des motions et celle des différents clichés. Les enfants ont été des familles assez moyennes de race allemande et de race celtique.

On a étudié les données en termes de *regard* vers l'objet, *l'approche* à lui, et la *préhension* de la main pour l'obtenir. On a trouvé un *regard* vers le bonbon en 9 sur 10 enfants à 20 semaines, et dans tous les enfants plus âgés. A 20 semaines la plupart des regards ne durent pas et ne sont pas accompagnés d'efforts pour obtenir l'objet, mais la durée des regards s'accroît rapidement avec l'âge, et à partir de 32 semaines presque chaque regard cause une réponse de préhension.

Le développement de *l'approche* est caractérisé d'une (1) précision plus fréquente dans le contact avec l'objet, laquelle devient presque parfaite à 28 semaines; (2) d'une plus grande approche directe, montrée par la plus petite distance à laquelle la main se lève au-dessus du haut de la table, par une plus grande tendance de la direction de l'approche vue d'en haut à être approximativement une ligne droite, et par un changement de la forme caractéristique de l'approche, du type ellipsoïdal au type planant; (3) d'un accroît graduel mais défini de la durée de l'approche, accompagné d'une plus grande capacité d'obtenir l'objet.

Le développement de la *préhension* est caractérisé d'une plus grande dominance et contrôle des doigts radiaux, finissant par une préhension précise par le pouce et l'index. Quatre types représentent les étapes impar-

tantes de la maturité de la réponse: la *préhension par toute la main*, une réponse primitive arrivant le plus souvent dans groupes les plus jeunes, laquelle ne réussit que rarement à obtenir l'objet; la *préhension palmaire*, une réponse un peu mieux contrôlée, où les doigts fléchissent dessous pour retirer le bonbon et le maintenir contre la base de la paume, employée principalement à 32 et à 36 semaines; la préhension à *ciseaux*, où le pouce est tiré contre le côté de l'index comme celui-ci fléchit dessous, pour obtenir le bonbon entre eux; et la préhension à *pinces*, où l'objet est pris entre les bouts opposés du pouce et de l'index. L'observation des enfants plus âgés et des adultes suggère que ce dernier type de préhension représente le plus haut degré de développement dans ce champ de comportement.

A 20 semaines nul sujet n'a réussi à prendre le bonbon. A partir de 36 semaines, tous ont réussi à le faire. A 52 semaines, la bonne qualité et l'efficience de la réponse, résultant dans une préhension rapide et forte, indiquent qu'elle arrive à un degré de perfection lequel existera avec peu de changements subséquents comme une partie du comportement total de l'individu.

CASTNER

DIE ENTWICKELUNG DES ZIERLICHEN FASSENS (FINE PREHENSION) BEI SÄUGLINGEN

(Referat)

Unter dem Ausdruck "zierliches Fassen" (fine prehension) versteht man das Erfassen von relativ kleinen Gegenständen mit der Hand, mit Erfordernis glatter Zusammenwirkung der feineren Bewegungen von Arm, Händen, und Fingern, und tüchtiger visueller Mitwirkung. Der Entwicklungsgang dieser Fähigkeit während des ersten Lebensjahres wurde untersucht durch Analyse der Reaktionen von Säuglingen auf ein kleines weisses Zuckerwerkkügelchen, ungefär 7 mm. breit, welches unter standhaften, bestimmten Bedingungen vor dem sitzenden Kind auf eine Tischfläche gelegt wurde. Die Situation wurde 59 Säuglingen, die die Alter von 20, 28, 32, 36, 44, und 52 Wochen vertraten, vorgelegt. Die Reaktionen wurden kinematographisch registriert. Aus diesen Registrierungen erhielt man dann durch Untersuchung der Bewegungen (motion study) und Analyse der einzelnen aufeinanderfolgenden Einrichtungen (frame-by-frame analysis) die in der Untersuchung verwendeten Daten. Die Säuglinge stammten aus approximativ durchschnittlichen Familien keltischen oder teutonischen Ursprungs.

Man erforschte die Befunde in Bezug auf die *Beobachtung* des Gegenstandes, die *Annäherung* daran, und die *Umschliessung* des Gegenstandes mit der Hand um ihn zu erhalten. Beobachtung des Kügelchens zeigte sich bei 9 aus 10 Säuglingen mit 20 Wochen, und bei allen älteren Säuglingen. Mit 20 Wochen sind die Beachtungen (regards) meistens flüchtig und von keinerlei Streben begleitet, den Gegenstand zu erfassen, aber die Dauer der Beachtung nimmt mit zunehmendem Alter rasch zu, und von 32 Wochen an löst fast jede Beachtung eine Greifreaktion (prehensory response) aus.

Die Entwickelung der Annäherungsfähigkeit wird karakterisiert durch: (1) zunehmende Genauigkeit bei der Etablierung des Kontakts mit dem Gegenstand (diese Genauigkeit ist mit 28 Wochen schon fast vollständig);

(2) zunehmende Direktheit der Annäherung, erwiesen durch eine Verminderung der Distanz der Emporhebung der Hand über die Tischfläche, durch eine zunehmende Tendenz des Annäherungspfades, von oben gesehen, nach der Richtung einer geraden Linie, und durch die Abänderung der anfangs schlingenarttigen (loop) Form der Annäherung in eine mehr planierende (planing) Art; (3) allmählige aber bestimmte Zunahme in der Beharrung der Annäherung, vereint mit zunehmmender Tüchtigkeit im Erlangen des Gegenstandes.

Die Entwickelung der Schliessung (closure), oder des Ergreifens, macht sich erkennbar durch zunehmende Dominanz und Kontrollierung durch die radialen Finger welche in genauem Ergreifen mit Daumen und Ziegefinger (precise thumb-index prehension) kulminiert. Vier Arten vertreten die wesentlichen Entwicklungsstufen der Reaktion: *Schliessung der ganzen Hand* (whole-hand closure), eine ungeschliffene Reaktion die am öftesten in den früheren Altersgruppen stattfindet, durch die es aber selten gelingt, den Gegenstand zu erlangen: *Ergreifen mittels Handfläche* (palmar prehension), eine etwas besser beherrschte Reaktion, wobei sich die Finger nach unten beigen so dass das Kügelchen nach rückwärts ziehen und es gegen dem untersten Teil der Handfläche festhalten—eine Reaktionsform die am öftesten im Alter von 32 und 36 Wochen verwendet wird; *die scherenartige Schliessung* (scissors closure), wobei der Daumen gegen die Seite des Zeigefingers gezogen wird, wärend letzterer sich nach unter biegt, so dass das Kügelchen so zwischen Daumen und Zeigefinger festgehalten wird; und das *pinzettenartige Ergreifen* (pincer prehension) wobei der Gegenstand zwischen den entgegengesetzten Spitzen von Daumen und Zeigefinger festgehalten wird. Beobachtungen an älteren Kindern und an Erwachsenen weisen darauf hin, das die letztgenannte Art des Fassens die höchste Stufe in der Entwickelung dieser Tätigkeitsart darstellt.

Mit 20 Wochen gelang es keiner der Vpp., das Kügelchen zu erfassen. Mit Anfang der 36sten Woche gelang es allen. Mit 52 Wochen weisen die Glätte und Tüchtigkeit der Reaktion, die zu raschen und fastem Fassen führen, darauf hin, dass das Fassen hier einer Stufe der Vervollkommung naht, die mit nur wenigen späteren Änderungen als ein Teil der gesammten Tätigkeitsausrüstung (behavior equipment) des Individuums weiter beharren wird.

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Child Behavior, Animal Behavior, and Comparative Psychology

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Child Behavior, Animal Behavior, and Comparative Psychology

THE GROWTH OF ADAPTIVE BEHAVIOR IN INFANTS: AN EXPERIMENTAL STUDY AT SEVEN AGE LEVELS*[1]

From the Clinic of Child Development, Yale University

By

HELEN M. RICHARDSON

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[1]This report is part of a dissertation presented for the Degree of Doctor of Philosophy in Yale University.

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I

INTRODUCTION

Statement of Problem

Toward the conclusion of his account of the problem-solving behavior of chimpanzees in *The Mentality of Apes,* Köhler remarks that in the study of human subjects "experiments of this kind can be performed at the very tenderest age" (20). Of all of Köhler's test situations, the simplest is that in which an accessible string is attached to an otherwise unattainable object. A practical demonstration of the possibility of such experimentation with young infants has been made in Gesell's tests of infant development (11). One of these tests consists in placing on a table top before an infant a red ring, 4 inches in diameter, about 14 inches away, with a 10-inch string making an oblique line to a point 6 inches forward of the child and 8 inches to his right. Observation of these experiments, combined with the interest earlier aroused by Köhler's work, led to the undertaking of a developmental study of infants in which a grill should be used as in animal experimentation and in which discrimination between an attached and an unattached string should be tested as well as the response to a single attached string.

Historical Summary

A complete review of the literature bearing on the adaptive behavior of infants in string problems would include the studies of infant development along motor,

sensory, and perceptual lines, and the studies of problem-solving by animals, infants, preschool children, and adults. We shall limit our review to the more or less experimental studies that deal specifically with the *utilization of strings for securing remote objects*, though we shall have occasion in our discussion to refer to the other literature indicated above.

The use of string problems as tests of adaptive intelligence begins with the comparative psychologists, whose interest in the problem-solving behavior of animals seems to have received considerable impetus from Thorndike's experiments reported in 1898 (32), 1901 (33), and 1911 (34).

Hobhouse (18) published in 1901 an account of some rather informal experiments performed in his home with his own dog and cat and those of his friends and at a zoo with a chimpanzee, a rhesus monkey, and an elephant.

The simplest problem called for the pulling down of a piece of meat from a shelf by means of a string that hung from a card on which the meat was laid. One cat failed to learn the appropriate response after more than 30 demonstrations, but finally achieved success on an occasion when a smear of fish called his attention to the string, and after this seemed to have substantially learned the trick. The explanation offered is that the animal had previously failed to notice the string, or that on one occasion he had noticed it and playfully snatched at it before the meat was on the card and had been led by this lack of success to disregard the string. Another cat pulled the string when

it was merely pointed to by the experimenter. One dog, after seeing one demonstration, took the string in his teeth and pulled the meat down, though in several succeeding trials he paid no attention to the string until the experimenter pointed to it. It was not until after his eighth trial that he became uniformly perfect. Other dogs showed less aptitude.

When a "dummy" string was suspended about a yard from the attached string, the latter always being on the same side, the dog from the first pulled the correct string if he saw the food placed on the card. After 8 trials he learned to pull the correct string first even if he did not see the food put up. When the position of the food was reversed between trials, more than 25 trials were required to perfect the discriminatory reaction. When the dog made an initial error, he always proceeded immediately to pull the right string; thus the incentive for correct initial choice was slight.

Another experiment called for "delayed reaction." Three strings hung down at intervals of about a foot, each attached to a card. The animal witnessed the placing of the food on a card, but could not see it after it was put up. On the first day the dog pulled in random fashion at first, but was correct in 7 of the last 10 out of 40 trials. On the second day conditions were "stricter." The dog was held back while the experimenter counted three, and then released. In the last 10 of 14 trials he was right 7 times. An early tendency to pull down the remaining strings after getting the food disappeared during the course of the experiment.

When a string attached to food was tied so that reach-

ing beyond the knot was necessary for effective pulling, the dog, the cat, and the elephant easily learned where to pull from the experimenter's pointing to the correct place, but the chimpanzee and the rhesus monkey spontaneously selected the part beyond the knot after not more than one trial at the nearer section.

A "hooked rope" problem was not mastered even by the chimpanzee. A rope was attached to a food container: one end of the rope came straight to the cage; the other end was passed around a stanchion some distance beyond the food box, then brought back and hooked to a bar of the cage. Pulling on the free end was ineffective unless the hook were removed.

Hobhouse concludes from these and other experiments that animals learn from attention to a simple sequence of events. The dog is capable of "practical ideas," which are defined as "a combination of efforts to effect a definite change in the perceived object," but these ideas do not represent any analysis of what is perceived. A "practical judgment" is "the correlation of a practical idea with a remote end." The chimpanzee gives evidence of "articulate ideas," in which "comparatively distinct elements are held in a comparatively distinct relation" (18, pp. 241, 270).

In the experiments of Hobhouse we find several types of problem that have been employed by later investigators: the single string attached to food; multiple strings; the "hanging string with the concealed objective"; the "tied rope"; and the "hooked rope." The interpretations suggested by Hobhouse have had considerable influence as well as his general methods.

De Jong (8) repeated some of Hobhouse's experiments, placing meat on a cardboard on a table with a string hanging down. He found that the dogs which he observed gave no evidence of "comprehending" the situation, and did not learn by imitation or by being "put through."

Franken (10) in 1909 made an extended series of string experiments in an investigation of the relation between instinct and intelligence in a dog. He emphasizes the need of noting all possible aspects of the behavior throughout the experimental series because one cannot tell what may prove to be significant. The experiments were conducted in his study, with the dog chained to a corner of the sofa.

A preliminary experiment showed that the dog was not interested in string *per se*. When meat was attached to the string, and the string lay directly between the dog and the meat, there was no attention to the string until after the experimenter had moved it back and forth and had twice drawn the meat a little closer. Then the dog suddenly snapped at the string and jerked the meat in reach. Success in this and the succeeding experiments are ascribed to the accidental appropriateness of certain instinctive movements. In a third experiment, where the success was prompt, there is a possibility that the movement was a perseveration from the preceding situation. In a fourth experiment, with the string laid in an arc so that it was not in line with the objective, the conclusion is that the experimenter's calling attention to the string led to a conscious reproduction of the earlier appropri-

ate behavior. Attention is called to the fact that different methods were used in pulling the string on different occasions.

In a later series of tests food was placed at various distances without any string attached; a loose string was laid down in various positions; and a string attached to meat was placed tangentially to the dog's position. Conclusions are that the behavior was influenced (*a*) by time factors (position of the test in the experimental series); (*b*) by spatial factors (distance of goal, position of the string in the visual field, length of the string, the possibility of looking over the situation as a whole); and (*c*) by the strength of the emotion aroused. As the experiment progressed, it appeared that the string alone tended to evoke the reaction that had originally been called forth by the objective proper.

Another series of experiments demonstrated that the food would be pulled in when it lay on a sheet of paper, or was attached to a stick, or was to be pulled down or hauled up by a string in the vertical plane. Franken compares this behavior with that of two little girls aged three years and two years, who used a hanging rope to pull down a pear from a tree. Since he concludes that they made use of perceptual thinking (*des sinnlichen Denkens*), he believes that we must assume that the dog has the capacity for primitive thinking, if only to a very slight degree. The dog's thinking is judged to have little perceptual content but to be characterized by a feeling of choice and of the direction of the course of the behavior.

The capacity for improvement of the native attentiveness was demonstrated by the decrease in the number of errors in a series of experiments where three strings of different colors were laid down 14 centimeters apart, the color and the position of the attached string being varied from one test to another. Early in this series the proportion of errors was greater than the chance expectation. This was found to be due to a preference for the string on the right, which was freer than the others from obstruction by the furniture in the room. During the course of these experiments there was an elimination of the response of drawing in a string before the meat was laid down or after the meat had been secured.

To test the dog's capacity for voluntary attention, in which *"dem Suchen eine Orientierung voraufgeht,"* a comparison was made between the response to a set of four differently colored strings when the arrangement was made (*a*) behind a curtain and (*b*) in full view of the animal. The number of errors was always less under condition (*b*), but during the course of the experiment there was a decrease in the proportion of errors under condition (*a*), and it was noted that the dog occasionally paused as if to look over the situation.

Franken's conclusion from the whole study is that the dog first reacts in an instinctive manner, with motor activity directed toward the objective. He learns the appropriate behavior only gradually through repetition. During the course of the learning the involuntary attention is directed more and more to the instrument and away from the objective. The motor

reaction is predominant; sensory [discriminative?] reaction is called forth only when it is necessary. Only in a few instances was there evidence of perceptual thinking. The latter is capable of development to a certain extent. Franken calls attention to a number of sources of error in his experiments: the hampering of the dog's efforts by the position of the furniture in the room, the fact that the dog was not always equally interested in the objective, and the fact that the experiments with colored strings were sometimes performed by daylight, sometimes by artificial light.

Shepherd (28), with nine rhesus monkeys as subjects, found that a food container to which was attached a string a yard long was promptly pulled into the cage, without evidence of trial and error. In a "tied string" experiment he obtained results similar to those of Hobhouse. In a later series of experiments (29) he found that dogs failed even in the simpler problem, but he suggests that this may be because their motor equipment is less suited to the problem than that of monkeys.

Köhler's experiments, referred to in our introductory paragraph, were made in 1914 and first published in 1917 (20). His subjects were seven to nine chimpanzees. He found that the chimpanzees never showed any hesitation about using a rope to secure an objective, either in the horizontal or vertical plane, and that the pulling was always "with an eye on the objective." A dog that he subjected to the same tests paid no attention to the string, though showing a lively interest in the objective. When two strings were laid down, one at-

tached to the objective and one with its distant end five centimeters from the objective, the one that appeared to lead more directly to the objective or the one on the right was likely to be pulled first. In some but not all of these experiments the two strings crossed each other. A single unattached string with its distant end one meter away and only two centimeters from the objective was pulled, though hesitatingly, with eyes and attention fixed on the objective. The string was always pulled if it visibly touched the objective. The distance from the objective at which the string would be pulled varied with the animal's degree of hunger and amount of attention.

A "diagonal string" problem was also used by Köhler. The remote end of the string was fastened to a heavy box; the string approached the cage in an oblique line. Food was tied to the string at a point that would be in reach only if the string were brought perpendicular to the front of the cage. All the six chimpanzees who could be induced to enter this experiment pulled first in the direction of the string. Two chimpanzees then proceeded immediately to pass the string from hand to hand along the bars until the food was in reach; two others reached this solution only after first trying to pull the string in the proper direction but on the wrong side of the bars. Two animals did not get beyond the direct pulling.

Köhler argues that the behavior of the chimpanzees in these situations was often characterized by "insight"; that is, that it seemed to arise "out of a consideration of the structure of a situation" (20, p. 190).

The experiment with a single unattached string at various distances from the objective, and the "diagonal string" problem are the two distinctly new situations found among these experiments.

Nellmann and Trendelenburg (24) applied tests like Köhler's to monkeys. They found that a rhesus monkey did not draw in a loose string where there was no food in sight, did not reach for remote food when no string was attached to it, but promptly seized the string and drew in the food when the string was attached to the food. Like Köhler's chimpanzees, the rhesus failed to distinguish between a string merely lying on the food and one that was attached. After some demonstrations in which the experimenter exaggerated the movements of laying down the string and of fastening it, he learned to govern his behavior by these gestures. If the food were displayed with the string coming near but not touching, the behavior was like that reported by Köhler except that after numerous repetitions the rhesus entirely gave up pulling the string when it did not visibly touch the food. A Pavian monkey failed to learn to refrain from pulling the string when he saw it merely laid on the food.

These investigators also used Köhler's "diagonal-string" experiment, with similar results. In a "hanging-string" experiment in which the food was put in a high basket so that it disappeared from the sight of the monkey, they found that the string was immediately pulled.

Nellmann and Trendelenburg distinguish between "primary" and "secondary" solutions. A primary so-

lution is one which arises when the specific problem, on the very first occasion of its being encountered, is solved without the aid of overt imitation, "trial and error," or "being put through." A secondary solution is one which does involve imitation, trial and error, or being put through. The solution of the diagonal-string problem by the rhesus monkey is considered to be "primary.'

Drescher and Trendelenburg (9), repeating the simple experiments involving distinction between an attached and an unattached string, found that a pithecus monkey displayed behavior similar to that of the rhesus, except that he did not learn to distinguish between the gestures of fastening the string and of merely laying it down on the food. They also tried to adapt the experiment to the motor equipment of cats and dogs by tying the accessible end of the string to a porcelain ring. Though the animals demonstrated by exploratory activity that they were able to manipulate the ring, they gave no evidence of perceiving the utility of the string.

Yerkes (38) employed some of the more complex forms of rope problems with the gorilla Congo. A form of the "diagonal-rope" problem was mastered with a little preliminary difficulty. In a "hooked-rope" problem the adaptation was gradual rather than sudden. A new problem of the "pull-rope" type called for pulling on a rope that passed over the top of the cage and drew a food container to a grill. The first successes appeared to be accidental. In a later trial the animal was observed to look along the overhead course

of the rope and then go to the proper place and secure it. This is given as evidence that she recognized the rope as a means of securing food even in a novel situation.

Guillaume and Meyerson (15) have included a *hooked-rope problem* and *two forms of diagonal-string* problems in their experiments with apes, but only a preliminary statement about these parts of their research apparently has been published. They emphasize, as Köhler also does, the distinction between the implement that is already placed in relation to the object and the implement that is separate from the object, and express the belief that the former is the level of the lower apes, the latter the level of the anthropoids and perhaps only of certain species. Guillaume (14, p. 101) refers to Bühler's experiment with a ten-months-old infant, which we describe on page 216, to show that the infant is at the level of the lower apes. He does not at the same time present evidence to show that the higher levels are beyond the ability of infants of this age, though he refers to an experiment by Köhler as evidence that a two-year-old can use a stick as a tool.

Teyrowsky (31) found that cats learned to pull on a rope to which was attached a board carrying food. At first they pawed directly at the food, and in doing this they encountered the rope and thus moved the food. He suggests that such an accident was necessary to show the animals that the board was movable, and expresses the opinion that "visual perception of movements is a function more original than visual percep-

tion of forms or states." In a hooked-rope problem persistent demonstration by the experimenter finally led to success by two of the subjects. The conclusion from these and other experiments is that cats are capable of practical judgment and articulate ideas.

Adams (1), studying adaptive behavior in cats, set problems both in vertical and horizontal pulling of a single attached string. The strings were in a cage and the cat outside. He found that some cats learned perfectly from one success, and asserts his conviction that with proper adaptation to the experiment *room* all cats would learn to pull strings in these situations and most of them would learn with one success. He also made a few experiments with arrangements of multiple strings; three parallel strings 30 centimeters apart, with food attached to the median string; three converging strings with the loose strings ending about 5 centimeters from the food; and roundabout and direct strings, with the food attached to the roundabout string. In the parallel-strings experiment the cat passed by a loose string and went on to pull the attached one. In the other experiments the cat, being introduced to the experiment room from the side opposite the grill where the strings were accessible, twice came around the cage on the side where the attached string was and pulled it first. On the one occasion when she came around on the side of the direct but unattached string in the roundabout-and-direct-strings experiment, she pulled the wrong string first.

Adams believes that the use of articulate ideas is indicated in at least two instances, and that the use of

practical ideas may be inferred in most cases. His conclusions from all his experiments are, among other points, that "motor and perceptual adaptation are indissolubly associated and develop concomitantly"; that insight is a "special case of adaptation both perceptually and behaviorally"; and that what is often called trial-and-error learning might be called a "small insight" and that what is frequently called mental trial and error might be called a "big insight."

Adams comments on the resemblance between his conclusions, those of Hobhouse, and those of Tolman (35), which appear at the end of a critical discussion of experimental studies of habit formation and higher mental processes in animals. Tolman's conclusions are in brief as follows: All learning involves the passing from one initial set of postulations of (insight into) the goal position to a second improved postulation of (insight into) the goal position. In trial-and-error learning this change comes only through overt behavior. In "insight" or "foresight" learning it comes without overt behavior, as a result of free play among representations of the ends of acts. The higher the animal, the fewer the number of experiences of an act which are necessary to achieve such representations, the clearer and more accurate such representations probably are, and the more it would seem they can be manipulated.

Tolman, in commenting on Nellmann and Trendelenburg's distinctions between primary and secondary solutions, makes the statement that one would not speak of a "solution" at all unless there were "some sort of internal happening then and there." This happening, he says, might be "*mental adding and subtracting of acts to*

produce new representations." Might one instead of saying that "the animal mentally adds and subtracts the acts," say that the addition and subtraction, the combining, *takes place* under the influence of the stresses arising from the animal's "drives" and the material provided by the present situation?

McDougall and McDougall (22, 23) emphasize the purposive character of the act of pulling in food by means of a string. They observed that a rat (22) and a raccoon (23) readily hauled up a dangling string to which food was attached, but distinguished between food and a non-edible object at the end of the string and after some errors pulled up only the food. Both animals varied their movements from one performance to another rather than repeating a stereotyped sequence.

Hertz (17) found that both a crow and a jackdaw hauled up food put in a pocket at the end of a dangling strip of cloth, though they did not attempt this method when the food was tied to the end of a string. The strip of cloth was an instrument better adapted to the motor equipment of the animal.

Investigators of infant behavior have emphasized the age at which objects are secured by means of strings and have sometimes suggested the theoretical implications or the factors contributing to make the behavior possible.

Dearborn (7) includes the following observations in the diary of his young daughter:

"*211th day. End of 30th week.*

I tried to make her pull on the coarse string attached to her toy elephant, but although she took hold of the string she could not be made to understand how to pull on it—this relation of action apparently at a distance is not yet empirically understood.

"*225th day. End of 32nd week.*
L. does not understand yet that by drawing on a string attached to an object, she can bring the object nearer to her.

"*228th day.*
L. now knows how to draws things up to her by pulling on a chain or string—e.g., as to-day my watch when it is out of her sight under her chair."

K. Bühler (6, pp. 48 ff.) made a more experimental study of adaptive utilization of a string in the first year of life, observing his infant daughter's reaction to a rusk tied to the end of a string and placed out of reach with the string coming in reach. The experiment was performed "once every few days." In the ninth month the child stretched out her hand directly to the rusk without appearing to notice the string. After a short time she appeared to have come to an understanding of the problem and made several correct solutions in succession, but this success was only temporary. Not until the end of the tenth month was the situation completely and permanently mastered so that the string was always looked for and pulled, no matter in what direction it lay. He concludes that this use of the string was "intelligent action" and not merely the result of training because (*a*) numerous repetitions allowing chance successes had not been characteristic of the experimental procedure; (*b*) there was evidence of transfer to similar but not identical situations; (*c*) the total bearing of the child indicated purposive rather than mechanically acquired action.

Peiser (26) includes string problems in a series of tests for children aged one to six years. His tentative norms are based on a study of children of the middle

class in Berlin, but the number of subjects is not stated. He reports that in the last quarter of the first year the child draws to himself the base on which the objective is placed. In the second year he acquires the understanding that the string is a means to an end, and in the third year it begins to be possible for him to master the crossed-string experiment. With a year-old child he found that the string coming in a direct line to the child absorbed the attention so completely that the objective proper was no longer regarded. A girl aged one and one-fourth years succeeded in securing the objective when the string came diagonally to a position at her left. He concludes that she was using the string as a means to secure the objective because she reached directly for the objective itself rather than for the string when the objective was placed in reach at the left and the string led off to a remote point in the median plane.

Gesell's "Ring-and-String" test, referred to in the opening paragraph of this paper, is briefly mentioned in his infant development schedule published in 1928 (11). According to this schedule the infant at nine months "uses the string and pulls the ring;" at twelve months "uses the string adaptively to pull the ring." In outline the procedure is as follows:[1] The Examiner holds the end of the string in his right hand, the ring in his left hand, and lays them on a table in front of the child in the position that we described above (p. 201). Further normative studies now in progress at the

[1]A full description of the method of presentation is to be published with the account of the normative study.

Yale Clinic of Child Development are resulting in a revision of the tentative published norms. Examinations have been made at four-week intervals from 16 to 52 weeks, 27 to 37 infants being observed at each age level. The infants were a highly selected group from American homes of average economic, social, and educational status and Northern European derivation. The following preliminary percentages have been made available from unpublished data of the Yale normative study. Out of the normative group, at 24 weeks none pulled the ring in reach, at 28 weeks 25%, at 32 weeks 47%, at 36 weeks 83%, at 40 weeks 95%. At 28 weeks 72% of those who pulled in the ring (18% of all the infants) gave some regard to the ring at the time of reaching for or pulling the string; at 40 weeks 92% (89% of all).

C. Bühler (5) and her assistants at the Psychological Institute of Vienna have made a series of 24-hour observations of behavior during the first year of life, observing five children of each month. Forty per cent of these children were from private homes and 60% were "institution children." They observed that the ten-months-old children frequently made use of a string to pull up a fallen rattle. In a series of "Baby Tests" from this Institute, "pulling an object by its string" is assigned to the eleven-months level. The test is described as follows: "A rattle or bell with a string attached is placed out of the child's reach. The end of the string is placed near or in the child's hand. The child pulls the toy toward him by means of the string." The significance of the test is stated thus:

"The child now understands that the string is a means of obtaining the toy which is otherwise out of reach." These tests were based on the inventory of behavior obtained from the 24-hour observations, and on a number of special investigations. The series was drawn up after making ten preliminary trials for each month, and finally the tests were given to 30 children in each month. The subjects were children in the *Kinderübernahmstelle* at Vienna.

Brainard (4) used the crossed-string experiment with his daughter aged 2 years 7 months as subject. He placed a stick of gum out of reach behind the vertical bars of an improvised cage, and tied to it a string one-half meter long. Three other strings the same length were laid down, one clearly away from the package though running toward it, the others crossing the right string and coming within two inches of the objective. Each string ended at a different opening between the bars. On the first trial all the wrong ones were pulled first. On the second trial, after being urged to look carefully first, she pulled first a wrong string, then the right one. On a third trial she was confronted with only two strings to choose from. The wrong one crossed and ended two inches from the objective. She held her hand for a moment before the wrong string, then pulled the correct one. In a diagonal-string experiment, the child first pulled in the direction of the string, then moved it along from space to space with her arm extended at full length through the bars. In a later trial she tossed the string from one opening to the next.

Lindemann (21) gave tests similar to Köhler's to feebleminded children and adults. His string problem consisted in the exposure of an objective towards which there led three converging strings. The left oblique string was attached and the other two were loose and crossed the attached string near the objective. From the fact that the median string was pulled first, Lindemann concludes that the behavior was governed by the optical structure of the situation rather than by the physical connection. This principle he found to hold true for the behavior of the majority of his subjects in his entire series of problems. He also found that his subjects might arrive at a solution of a problem on one occasion without being able to repeat it later. This behavior he compares with the apparent temporary understanding of the string connection by Bühler's nine-months-old child. He comments on the fact that the subjects did not take the time to look over the situation, but chose immediately without testing to see which was the right string.

CHARACTER OF THE PRESENT STUDY

Previous investigators of infant behavior in the utilization of strings have not made the objective genuinely inaccessible to a child who can creep or climb. The method of presentation has been such as to emphasize the string as much as the objective proper. Discrimination between attached and unattached strings seems not to have been studied, except in the crossed-string experiments with two-year-olds reported by Peiser (26) and by Brainard (4). Systematic periodic ex-

aminations of a group of 16 infants, use of a grill, arrangement of situations behind a screen, and supplementation of the single-string tests with a graded series of multiple-strings situations were distinguishing features of the present investigation.

II
METHOD
Subjects

The subjects were 10 boys and 6 girls who were examined every four weeks from the age of 28 to 52 weeks inclusive. All examinations fell within two days before and two days after the exact date with the exception of three instances where a postponement for one additional day was unavoidable.

The aim in making up the group was to have it as homogeneous as possible.

The length of pregnancy in no case exceeded, or fell short of full term by more than 15 days.

In respect to order of birth, the group was distributed as follows:

	First child	Second child	Third child	Fourth child
Number of cases	10	4	1	1

The racial origin of the group is shown in Table 1, the percentages being based on the derivation reported for the grandparents.

TABLE 1
Racial Origin of Group

Nationality of grandparents	Percentage
English, or "American far back"	61.5
Scotch	7.8
Scotch-Irish	5.5
Irish	8.6
Welsh	3.9
German	7.8
French	3.1
Dutch	1.6
American Indian	.2

TABLE 2

EDUCATIONAL STATUS OF PARENTS AND GRANDPARENTS

Highest degree or school year reached	Father	Mother	PGF	PGM	MGF	MGM
M.D. or Ph.D.	6	1	1	—	3	—
M.A. or M.S.	4	3	—	—	1	—
B.S., B.A., or Ph.B.	5	5	3	1	1	—
3 years college	—	3	—	—	1	—
2 years college	—	—	—	1	1	1
1 year college	1	—	—	—	—	—
Normal school graduate	—	—	—	1	—	1
Law office	—	—	1	—	1	—
Business training	—	—	1	—	1	—
Girls' school, seminary	—	2	—	3	—	7
High school: 4 years	—	1	3	3	3	3
3 years	—	—	—	—	—	—
2 years	—	—	—	—	—	—
1 year	—	—	—	—	—	1
Night school	—	—	1	—	—	—
Grammar school (6-8 grades)	—	—	3	2	4	3
Not reported	—	1	3	5	—	—

TABLE 3

DISTRIBUTION OF PARENTAL AND GRANDPARENTAL OCCUPATIONS AMONG THE GOODENOUGH OCCUPATIONAL CATEGORIES

	Percentage of total Minneapolis population	Father	PGF	MGF
Group I	5.4	13	4	7
Group II	6.3	3	4	5
Group III	37.3	—	4	1
Group IV	24.3	—	2	3
Group V	14.9	—	—	—
Group VI	11.8	—	—	—
Not reported	—	—	2	—

Since the purpose of the study was to analyze development rather than to establish norms, no attempt was made to have the group "normative" in social and economic status. The group was selected on the basis of superior educational and occupational status of

parents. The educational status of the parents and grandparents is presented in Table 2. The distribution of the parental and grandparental occupations among the Goodenough occupational categories (13, Appendix A) is given in Table 3 and the Barr Scale ratings (30, pp. 66 ff.) of the occupations are summarized in Table 4.

Apparatus and Mode of Procedure

The examinations were all given in one of the regular examining rooms of the Yale Clinic of Child Development. The room was small and plain, illuminated by diffuse electric light from an overhead source. The window shades were drawn, or in warm weather the window was screened from view. A one-way observation screen at the side of the room to the infant's right concealed the stenographer who took down the Examiner's running account. The infant's mother viewed the examination from behind this screen unless her presence was needed in the examining room. Aside from the examination crib and the mother's chair, the room contained no furniture that was visible to the infant.

A standard white-enameled iron crib with side railings 16½ inches (41.91 cm.) high was the immediate scene of operations (Figure 1). The toys to be used as lures were kept in the material bag at the head end of the crib. A wooden platform 27x51 inches (68.58x 129.54 cm.) was set over the springs and was covered by a large light-gray blotter laid on a cotton pad and rubber sheet. For infants who were not yet able to

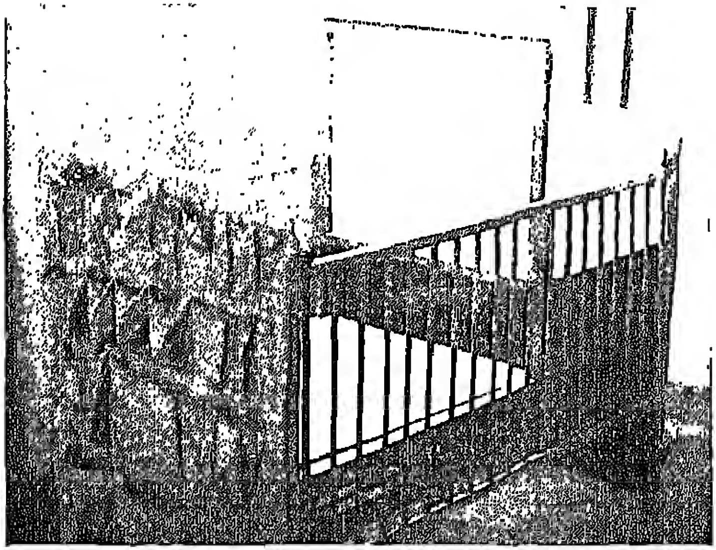

FIGURE 1
EXAMINATION CRIB WITH TABLE AND GRILL

maintain good balance in the free-sitting position, a small adjustable morris chair with a canvas back and seat and supporting band was provided. The foot end of the crib was occupied by a 20x27 inch (50.8x68.58 cm.) table with legs adjustable to heights of 6, 7½, and

TABLE 4
BARR SCALE RATINGS OF PARENTAL AND GRANDPARENTAL OCCUPATIONS*

	Father	P G F	M G F
Highest	17.5	17.5	17.5
Lowest	13.5	10.8	9.4
Mean	15.77	13.72	14.38

*The mean Barr Scale rating for the occupations reported in the 1910 census for Los Angeles, San Francisco, and Oakland, California, is 7.92. (30, p. 71).

9 inches (15.24, 19.05, 22.86. cm.). A grill 27x22 inches (68.58x55.88 cm.), with brass rods making 3x4 inch (7.62x10.16 cm.) spaces, furnished a barrier at the edge of the table top, the upper surface of the lower grill frame being flush with the upper surface of the table. The grill could be removed by sliding it up on the side supports. The table and the wooden frame of the grill were painted light gray.

The vertical rods of the grill and the spaces limited by them are designated in the protocols by the numbers 1 to 7 and 8, respectively, counting from left to right, and the horizontal rods and corresponding spaces are designated by the letters *A* to *D* and *E*, reading from the bottom up. Thus, Space 5*A* is the space just to the right of the center in the row nearest the table top; 6*B* is one space farther to the right and one row higher.

The lures employed were a squeaking cat of red rubber, a roly-poly doll colored yellow, blue, green, and orange, a yellow wooden duck with red wheels, a white rubber ball with a narrow red-and-green equatorial stripe, a blue celluloid automobile, and a celluloid "fish" of a bright clear orange red, a Japanese toy composed of an egg-shaped anterior section attached to a hemispherical posterior section, the fish nature being suggested by sketchy black markings. All the lures were of approximately the same general size, a little smaller than the 3x4 spaces of the grill.

The strings were of twisted and doubled white twine, 18 inches (45.72 cm.) in length.

The situations presented fall into two general

groups, which may be designated respectively as Single-String Situations and Multiple-Strings Situations. The settings for each type are shown in Figure 2. All of the settings were laid a little off center in order that the lure should not be directly behind Bar 4. Space 5, rather than Bar 4, was the center. Penciled marks on the table top indicated to the Examiner the exact positions for the lure and the ends of the strings. The near ends of the strings were at the edge of the table.

In the Perpendicular-Parallel-Strings Situation the strings were 7 inches (17.78 cm.) apart. In the Oblique-Parallel-Strings Situation the distance between the ends of the strings at the edge of the table was 3 inches (7.62 cm.) In the Converging and Roundabout-and-Direct-Strings Situations the loose strings ended about 2 inches (5 cm.) from the lure.

All settings were arranged behind a cardboard screen. Immediately after the screen was removed, the lure was tapped on the table, squeaked, rocked, or rattled by the Examiner.

When the screen was removed, the infant was in position at the center, seated before the table. At the ages of 44 to 52 weeks the infant was very likely to pull himself to standing between presentations and cruise about the crib. In such cases the usual procedure was for the mother to assist by holding the screen and removing it as the Examiner seated the child in position. Occasionally it seemed better for the Examiner to remove the screen as the mother seated the child. In one case where the screen seemed to be a distinct source of

irritation, the mother kept the child's attention at the head end of the crib while the Examiner arranged the strings. In very rare instances the infant was allowed to stand, but no cases are included where he did not enter upon the situation in a central position with reference to the array on the table.

If the infant secured the lure, he was allowed to play with it for a short time before it was removed. Sometimes the removal of the lure was aided by distraction of activity to the screen, or by waiting until it was accidentally dropped. At 52 weeks the infants occasionally cooperated by holding out and releasing the lure to the Examiner either spontaneously or in response to "Give it to me."

The Examiner always was stationed at the child's left, except in four of the examinations at 28 weeks. The mother's position when she was in the room varied to meet the exigencies of the situation. Usually she sat a little distance from the left foot end of the crib. Occasionally she stood at the child's right.

Time records were taken by the Examiner with a stop-watch. A running account of the procedure and the child's behavior was dictated by the Examiner to a stenographer. This record began with the introduction of the infant to the reception room and included an account of the warming-up period and of the child's behavior between situations.

Examinations were scheduled for a time of day that would fit the infant's daily routine of sleeping and feeding. The most frequent hours were between 8:30 and 9:30; between 12:30 and 1:30 (up to 44 weeks); between 2:00 and 3:00; and between 3:30 and 4:30.

The median duration was 33 to 39 minutes at 28 through 40 weeks and from 45 to 50 minutes from 44 through 52 weeks.

Order of Procedure

The order of procedure of the examination is outlined below.

A. Warming-up Period. When the infant was seated before the grill, a one-inch red cube was placed on the table top directly in front of him (*a*) 2 inches (5 cm.) from the edge, (*b*) 14 inches (35.56 cm.) from the edge, (*c*) 2 inches from the edge.

B. String Situations.

1. Single-String arrangements (*a*), (*b*), and (*c*) were successively presented with the grill in position. (This situation will be referred to hereafter as "Single String with Grill" and will be represented in the charts by the letters *SG*.) If there were success with (*a*) and (*b*), (*c*) was omitted. If there were failure with (*a*) and (*b*), the grill was removed after (*c*), and (*a*), (*b*), and (*c*) were repeated with the open table top. (This situation will be referred to as "Single String without Grill," and represented by the letter *S*.)

2. If the infant pulled the lure in reach in arrangements (*a*) and (*b*) in the situation "Single String with Grill," the grill was retained and the multiple-string arrangements in the order shown in Figure 2 were presented as far as success and interest seemed to warrant. (These situations will be referred to by the names used in Figure 2; by the initial letters of these names—*PP, OP, C, RD;* or by the symbols representing position (*a*) in each case.)

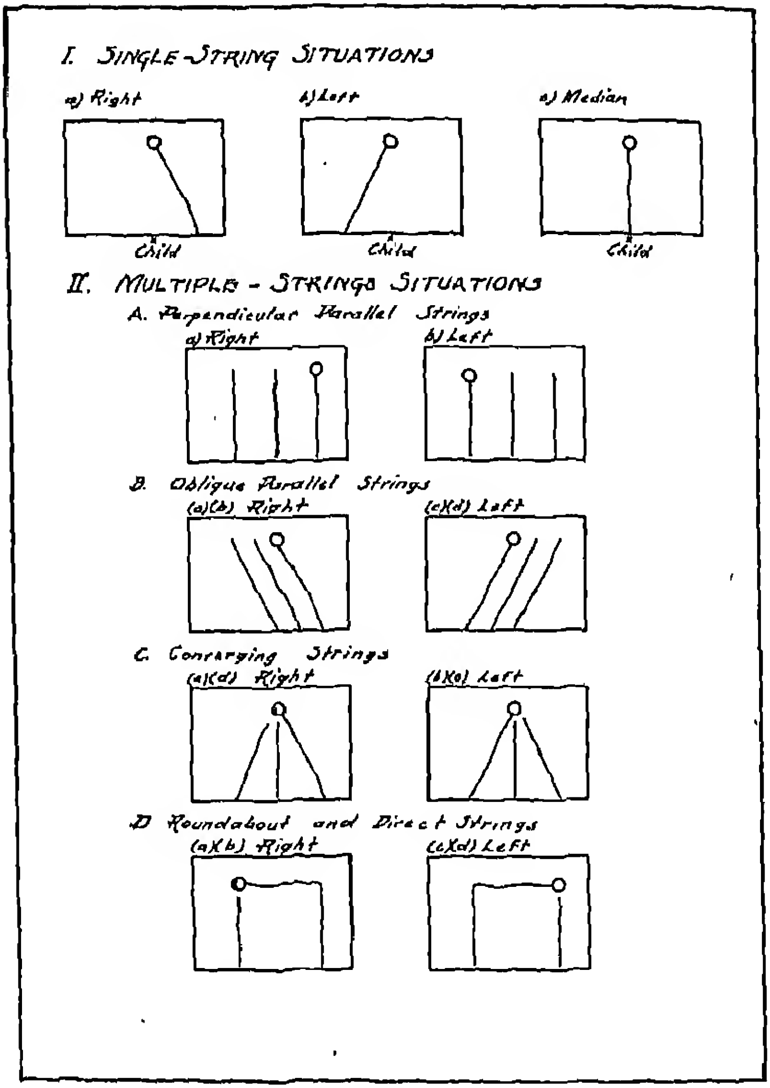

FIGURE 2

PLANS OF THE SEVERAL SITUATIONS

The letters (*a*), (*b*), (*c*), and (*d*) indicate the order of presentation.

Infant	No.	28 Weeks	32 Weeks	36 Weeks	40 Weeks	44 Weeks	48 Weeks	52 Weeks
Boy A	a					X X	X X X	X X X X
	b					X X	X R	X X
Boy B	a	X X	X X	X X	X X	X X X	X X X X X	X X X X X
	b	X X	X X	X X X	X X	X X X X		X X X X X
Boy C	a	X X	X X	X X X	X X X X X	X X X (1) X	X X X X X	X X X X X
	b	X	X	X X	X	X X X X X	X X X X	X R
Boy D	a	X		X	X X	X X	X X X	X X X X X
	b	X		X	X X	X X		
Boy E	a	X X	X X	X X	X	X X		
	b	X X	X X	X X		X X		
Boy F	a	X X	X X	X X	X X X X	X X X X	X X X X X	X X X X X
	b	X X	X X	X X X	X X X	X X		
Boy G	a	X X	X	X X X	X	X X R	X X X	
	b	X X	L X			X X R	X X	
Boy H	a		X				X X R	X X X X X
	b		X X				X	
Boy J	a		X X	X X	X X X X X	X X X X X	X X X X	X X X X X
	b		X X	X X R			X	
Boy K	a	X X	X X	X X	X X X	X X		
	b	X X	X X	X X	X	X X X		
Girl A	a	X X				X X X	X X X X X	X X X X X
	b	X X				X X X		X X X
Girl B	a	X X	X X	X X	X	X X X	X X X	X X
	b	X X	X X	X X	L X	X X X		
Girl C	a	X X	X X	X X	X X	X X		
	b		X	X X	X			
Girl D	a	X X	X X	X X	X X	X X	X X X X X	X X X X X
	b	X X	X X	X X	X X	X X	X	
Girl E	a		X X	X X	X X X	X X X	X X X X	X X X
	b		X X	X X	X	X	X X X X X	X X X X X
Girl F	a	X X	X X	X X	X X			
	b	X X	R X	X X	X X			
		11 12	12 13	7 13 8 5	4 13 7 5 3 2	14 14 9 4 2	12 12 12 8 8	11 11 10 10 9

FIGURE 3

SITUATIONS USED WITH EACH INFANT AT THE SEVERAL AGES

a—before lever situation; *b*—after lever situation. *R* and *L* signify that the presentation was made only in the right or left position. (1) Stenographic record inadequate.

C. Lever Situations. Some situations were presented in which a lure was to be secured by the rotation of a horizontal lever. The results of these experiments are not reported in this paper.

D. String Situations. If time and the infant's interest warranted, the string situations, as outlined above, were repeated. They were more likely to be repeated when the examination had not been lengthened by the introduction of more than two Multiple-Strings Situations.

In later references to the string situations, the presentations before the lever situation will be referred to as *R1, L1, M1,* and those after the lever situation as *R2, L2, M2.* The letters designate the direction of the attached string (Right, Left, Median).

III
THE EXAMINATIONS

Figure 3 shows exactly what situations were given to each infant at each age and were used in the compilation of results. Boy A was examined at all the ages before 44 weeks, but his early protocols have been discarded because the procedure was not at that time in its final form. The protocols for Girl A between 32 and 40 weeks have been discarded because at 32 weeks she showed a distinct fear response to the objects attached to strings. To overcome this fear she was given specific home training in pulling in reach an object similar to one of the experimental lures. From 44 weeks on, her inclusion seemed justified because her behavior was not markedly different from that of the infants without special training. Examinations of Boy E at 48 and 52 weeks, of Boy H at 28 weeks, and of Girl C at 52 weeks were a complete loss because of fussing or poor adjustment, and were not reattempted on a second day because there seemed no assurance of a more favorable outcome. These records have been left out in compiling the results. Other gaps in the chart are due to illness of mother or child, to absence from town, or to the youth of the infant at the conclusion of the experimental work.

Other departures from an unbroken uniformity of procedure probably should be noted also.

There were four instances in which lack or abbreviation of the regular nap resulted in an infant's being very irritable when he came for the examination. These infants returned on a second day in a more favorable condition, and the second examination has been substituted for the first in the treatment of results. The case of Girl D at 32 weeks is a little different from the other three of the

above four, in that her best performances on the two days have been drawn upon to make a complete examination.

The examinations of Boy E and Boy G at 40 weeks were abbreviated by fussing, but a return engagement was impossible. In cases like these where the examination was brought to an untimely close in the midst of an advanced situation, the presentation which determined the conclusion was not counted if it was evident that the session should have terminated earlier. On the other hand, numerous records of behavior more or less marked by fussing have been included.

Occasionally a child showed very little interest in the lure displayed on the table, but a second trial with a different lure brought heightened activity. Such second presentations were offered and their results used in instances amounting to 1% of the total presentations at 32 weeks, 4% at 36, 40, and 44 weeks, and 2% at 48 and 52 weeks. A re-presentation with the same lure but less fussing or motor distraction has been substituted in a number of presentations amounting to less than 2% of the total presentations at 40 weeks and less than 1% at 44. The repetitions in these cases were given in the hope that the conditions of the situation might approach more nearly to normal.

One or two other cases of second chances that revealed significant behavior will appear in the analysis of the material.

As the foregoing discussion of irregularities suggests, the infants were found to differ considerably in their emotional adjustment to the examinations. A classification into four groups on this basis, giving the

TABLE 5

EMOTIONAL ADJUSTMENT OF THE INFANTS TO THE EXAMINATIONS

Quality of adjustment	Number of infants 28-40 weeks	44-52 weeks
A. Adjustment excellent	3	2
B. Adjustment almost always good	3	5
C. Adjustment good about half to five-sixths of the time	7	5
D. Adjustment precarious at least half the time; rather consistently irritable	3	3

number in each group, appears in Table 5. The division into two age groups is necessary because some infants were consistently better adjusted when they were younger and some when they were older. Increasing age brought one infant down from Group C to Group D, one from Group A to Group B, one from Group B to Group C. On the other hand, one moved up from C to A, one from C to B, and one from D to B.

IV
NATURE OF THE PROTOCOLS AND GENERAL METHOD OF ANALYSIS

Two Sample Protocols

The raw material from which were assembled the organized results to be given in the two succeeding divisions was the report dictated by the Examiner. In order that the reader may approach these sections with some idea of the nature of the original material, portions of the protocols for Boy C at 28 and 36 weeks are quoted here. Extracts from other protocols will be examined later in relation to specific questions.

Boy C, 28 Weeks

4:04 P.M. Boy C is brought into the examining room and set in the chair. He kicks with his feet on the platform and rubs them together; smiles at the Examiner as he is moved up to the grill. Immediately raises his right hand and grasps Bar 6 at junction with Bar *A*; raises left hand up to the grill and looks at the Examiner and smiles.

[Record of the cube situation is omitted.]

4:04 P.M. *Single String with Grill*

R1. Screen is set up and cat is put in place with the *string on the right.* C, meanwhile, has been actively showing signs of fussing while he scratches at the screen approaching his mouth towards it. Screen is removed; cat is squeaked. C regards the cat rather fixedly and leans forward opening his mouth while approaching it to the grill and moving both of his hands about actively on the grill, left hand at 3 and 4*A*, right hand at 5 and 6. After 35 seconds his right hand almost touches the string but he *does not look* at it.

L1. *String is moved to the left* behind the screen; the screen is removed and the cat is squeaked. C moves his hands about on the grill again, fussing somewhat as he regards the Examiner and leans over to the right. After 30 seconds the child becomes quiet but only momentarily. He is given the cube. Carries to his mouth.

M1. String is moved to median behind the screen and the screen is removed; cat is squeaked. C regards the cat, then the Examiner, meanwhile moving his left hand up and down on the lower edge of the grill. He contacts the string but does not look at it; rather he clasps and unclasps his right hand on Bar *B* and kicks his feet on the platform; apparently he pays no particular attention to the string. Begins to fuss. He is moved away from the grill by the Examiner and is given the cube to hold while *grill is removed.*

4:10 P.M. *Single String without Grill*

R1. Cat is put in place behind the screen with the *string on the right.* Screen is removed and cat is squeaked. Boy C brings his right hand down on the string; he scratches at the string and picks it up only to release it again, occasionally glancing at the cat and scratching at the table top. He is moved slightly closer to the table by the Examiner. With his right hand he scratches at the string but does not pick it up; only straightens it out; then pounds the table top. Finally he secures the string between the thumb and forefinger of his right hand and pulls it in, meanwhile regarding the Examiner. Cat is now half way across table, but the child does not pay further attention to it. Pulls the string in, watching it move, but does not notice the cat. Releases the string, which is hanging over the edge of the table. Cat is almost in reach, but C does not try to get at it. He pats the table top, meanwhile contacting the string but paying no attention to it. Presently he jerks string, pulling the cat within reach. He prehends it by its tail with the thumb and middle finger of his right hand, bringing it to the center of the table towards his left hand; vocalizes satisfaction and carries cat to his mouth about 20 seconds after he took hold of it first. Total time required: 1 minute 55 seconds. Cat is removed by Examiner with considerable difficulty.

L1. Cat is put in place with *string on left;* screen is removed; cat is squeaked. C pats the table top; contacts string with his left hand. Picks up string but releases it again. Once more he closes his left hand over the string, but releases it to turn his attention to patting the table. Fusses audibly; brings both hands to his mouth. Left hand occasionally contacts the string, but C does not pull it in. Finally he grasps the string with his left hand and brings it to the median position. Regards string and momentarily carries it towards his mouth. After 1 minute 30 seconds screen is set up. C scratches at it.

M1. String is in *median* position. Screen is removed. C's hand knocks string out of place, necessitating re-instatement of screen and situation. Cat is squeaked and child regards it, then pounds on table. Meanwhile his left hand catches on the string, moving it up and down, but he does not take hold of the string. After 30 seconds, since C is fussing forcefully, the cat is removed. C is given the cube while he is moved away from the table; he carries the cube to his mouth.
[Record of the lever situation and of the string situations following it is omitted.]

Boy C. 36 Weeks

4:03 P.M. When Boy C is brought into the examining room and set in the crib by the Examiner he begins to cry. He is crying very hard and he is not distracted by either the ball or the red ring which he is given to play with. As he is crying very hard, his mother is asked to come into the examining room. She sits on the left side of the crib. Since C continues to cry, his mother picks him up and holds him on her lap for a little while. When C quiets again he is given the red ring to play with and after a while he picks it up and chews it. He stops crying but presently resumes it.
[After about 10 minutes he was replaced in the crib. Additional time was required to make adjustment complete. Finally the cube situation was successfully carried through, the cube being picked up when it was presented in the near position.]

4:23 P.M. *Single String with Grill*

R1. The cat is set up behind the screen with the string on the *right.* The cube is taken away and the screen is removed. The cat is squeaked. C looks open-mouthed at the cat, looks off to the right and looks back at the cat. He looks at the Examiner and smiles, sighs, and looks back at the cat. He raises his left hand towards the grill. He is moved a little closer to the grill by the Examiner, who squeaks the cat again. C looks at the cat, looks at the Examiner and smiles. He looks back at the cat and pushes with his left foot on the platform. He looks at the cat, looks off to the right and sneezes. The screen is set up after 1 minute 30 seconds.

L1. The string is moved to the left. C is moved into a little better position. The screen is removed while C is scratching at it. The cat is squeaked. Again C looks at the cat; then he looks at the string on the left. He immediately reaches for the string with

his left hand. . With one tug he pulls the cat to the edge of the table where he immediately takes hold of it with his left hand. He also brings up his right hand. Time: 25 seconds. After 30 seconds C has taken the cat through the grill and carried it to his mouth. He removes it for inspection and looks at the length of the string which he is holding in his left hand while holding the cat in his right. He repeatedly mouths the cat and removes it frequently for inspection.

M1. The cat is removed and put in place behind the screen with the string in the *median* position. The screen is removed while C is protesting slightly. The cat is squeaked; C looks at it, looks at the Examiner, looks back at the cat, looks at the string and picks it up with his right hand. He pulls the cat about two-thirds of the way across the table and stretches for it through Space 3*A* with his left hand but he is not close enough to the cat to reach it. He picks up the string with his left hand, pulls the cat to the edge of the table and immediately tries to pick it up. He is successful and carries it to his mouth. Thirty seconds were required for making the first contact with the cat.

4:29 P.M. *Multiple Strings*

[In these quotations the records of setting up and removing the screen and of the infant's behavior after securing the lure and between situations have been omitted or abbreviated.]

Perpendicular Parallel Strings

R1. The cat is removed and the screen is removed, revealing the roly-poly doll. This quiets C's protests. He looks at the roly-poly doll as it is rocked. He reaches for the right-hand string, which is the correct one, and pulls the doll to the edge of the table with one tug. When it is within reach, he tries to get it with his left hand. The doll rolls out of reach. He pulls it in with the string, which he is still holding in his right hand. He brings the doll to the edge of the table and this time he brings it clear off the table by means of the string and dangles the doll by the string before trying to take hold of the doll. He carries the doll to his mouth. Time: 40 seconds.

L1. C protests at removal of the cat but ceases when he sees the roly-poly doll being rocked. While looking at it, he reaches for the string on the left, which is correct. He takes it first in his right hand, then in his left. He transfers it to his right hand as he pulls

the doll to the edge of the table. It required 20 seconds to bring the doll to the edge of the table. He regards the string, transferring it from hand to hand. Finally secures the doll after 30 seconds.

Oblique Parallel Strings

R1 (*a*). C, looking at the duck, reaches over to the right, scratches at the right-hand string. Since it snaps out of reach, the Examiner moves it within reach. He continues to scratch at it rather than other strings. He takes hold of it, pulls the duck partly in across the table, then to the edge of the table, looking at it as it comes in. He is looking back at the string in his hand and approaches the duck with his hand but gives another pull to the string which brings the duck swinging off the edge of the table. The time required to get the duck off the table was 40 seconds. C is vocalizing repeatedly.

R1 (*b*). C takes the median string; pulls it in while looking at the duck. He pulls it in with his right hand, then looks back at the duck, takes the left-hand string, pulls it in, looks at the string, which he raises and lowers. He looks at the Examiner in a somewhat protesting way, looks back at the duck, and reaches for the string on the right, pulls the duck to the edge of the table and off the table. Vocalizes satisfaction.

L1 (*a*). C, looking at the ball, picks up the right-hand string with his right hand and pulls it in. He looks back at the ball while holding the string which he has secured. He carries his hand back to the grill, looks back at the string in his hand, and looks at the ball and scratches the platform. He looks along the length of the string which he is holding in his two hands. He looks momentarily back at the ball but looks off to the right where he hears the sound of the stenotype machine. He looks at the Examiner and smiles. As the Examiner reaches for the ball, again C's attention is called to it and he takes the median string, pulls it in, and quickly drops it and looks back at the ball. He reaches with his left hand for the left-hand string and brings the ball rolling off the table.

L1 (*b*). C immediately pulls in the median string. Then, looking back at the ball, he takes hold of the left-hand string with his left hand and brings the ball rolling off the table to the platform. He picks it up by a bit of the string close to the ball and holds it thus dangling. Fifteen seconds were required to get the ball in this way.

[The remainder of the record is omitted.]

Boy C at 28 weeks presents a behavior picture very characteristic of the group at that age. At 36 weeks he is somewhat in advance of the majority of his fellows of equal age. The juxtaposition of the two pictures makes evident the difference produced by eight weeks of growth: clearly a difference in perceptive attitude toward the string and also a difference in response to the grill, in method of approach to the string, in method of pulling, in postural control, in social and emotional adjustment.

General Method of Analysis

From the protocols a long list of classified and temporally grouped behavior items was made for each situation. At each age the items found in each presentation were checked in parallel columns, a column for each infant. The frequency with which each item occurred at a given age was found. The items which appeared to be most significant were then selected. Their frequencies, divided by the total number of presentations of the given situation at the age in question, furnish the percentages which are used in most of the accompanying graphs.

Though right, left, and median presentations in the Single-String Situations were kept separate in the tabulations, all have been combined in the final percentages. It was found that percentages based on the total number of presentations and percentages based only on the oblique (right and left) presentations never differed by more than 3 points from 36 weeks on, and rarely more than 5 points at 28 and 32 weeks. Where

there was a difference, the inclusion of the median presentations raised the percentages of the more "adaptive" behavior.

V

ANALYSIS OF THE MATERIAL: SINGLE-STRING SITUATIONS

Effect of Age on the Behavior in the Situation with Grill

Some of the more evident changes which age wrought in the behavior are presented first, with a few comments. A further analysis, with suggestions as to explanations of these changes, is made in the sections dealing with the effect of the grill, motor capacity for prehension and pulling, and perceptive attitude.

The influence of age on the general gross-motor and social-emotional behavior pattern is suggested by the ascending lines in Figure 4. At 28 weeks none of the infants were able to sit alone. From 40 weeks on, almost all were sitting unsupported on the crib platform. The one infant who sat in the chair at 48 and 52 weeks had been creeping with agility since 36 weeks, and preferred a semi-creeping position to free sitting, though he tolerated the chair well enough. The increasing frequency with which the mother was needed in the examining room as the age advanced is an index both of growing social perceptivity and sensitivity, and of the tendency to pull to standing and cruise about, which made assistance to the Examiner highly desirable.

Though these aspects of behavior are not specific to the lure-and-string situation, they are distinctly present along with the more specific behavior items and

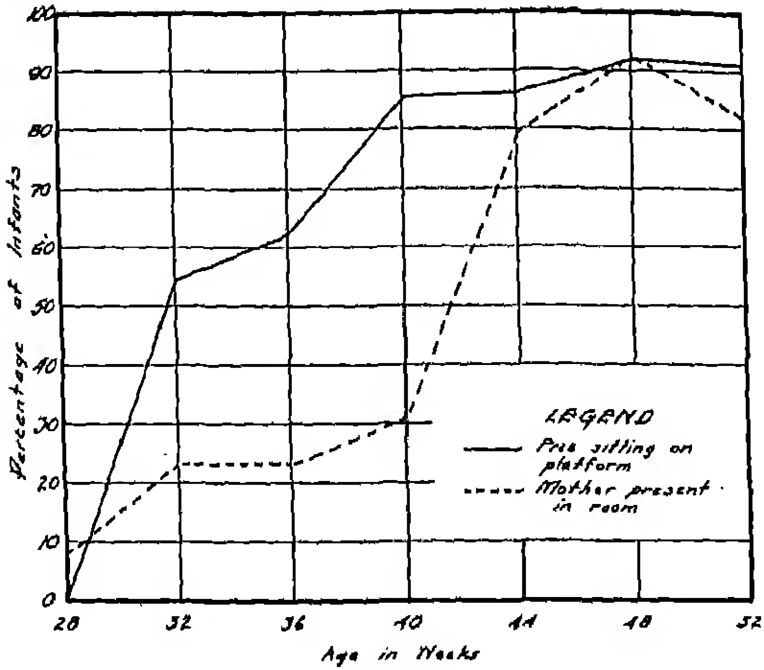

FIGURE 4

General Motor and Social-emotional Development
Situation: Single String with Grill

form a part of the total picture of a developing organism.

The development of adaptive behavior may be read in Figure 5. By adaptive behavior is meant behavior which is fitted most economically to relieve the "tension" which one may suppose is created by the presence of the remote lure. Clearly the pulling of the lure in reach is a function of something that takes place between 28 and 44 weeks. In addition to the sharp rise of the line which indicates the pulling in reach of the

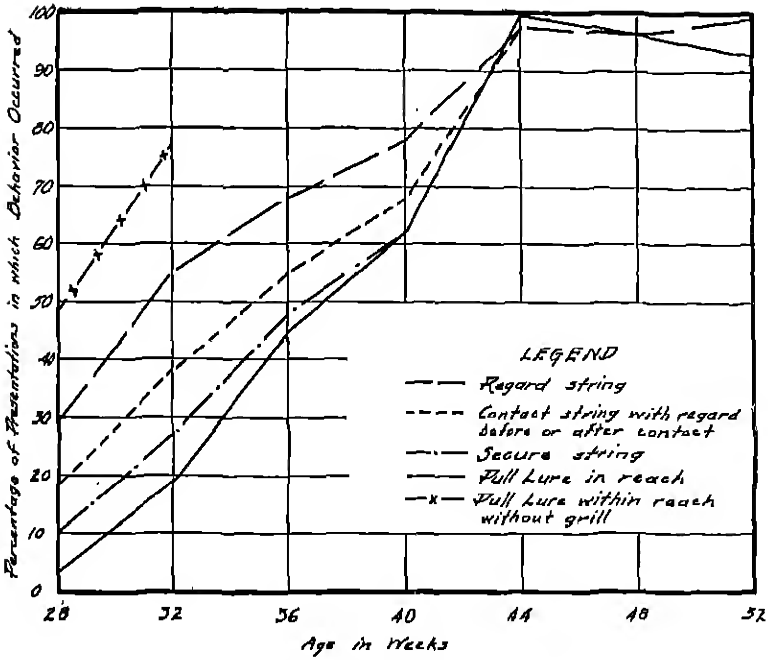

FIGURE 5
DEVELOPMENT OF ADAPTIVE BEHAVIOR
Situation: Single String with Grill

lure, one may note the converging of all the lines between 32 and 44 weeks. At 28 weeks the string was regarded more frequently than it was regardfully contacted, was contacted more frequently than it was secured, and was secured more frequently than it was pulled far enough to bring the lure in reach. But at 40 weeks securing of the string was always accompanied by pulling the lure in reach, and at 44 weeks the lure was always pulled in reach, though in rare cases it was merely dangled or left on the table or platform and not grasped.

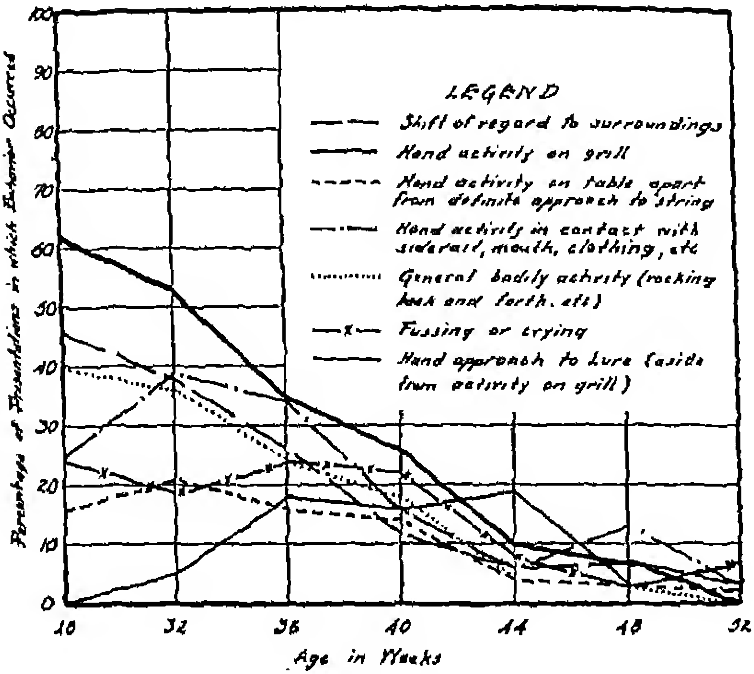

FIGURE 6

DROPPING OUT OF THE LESS ADAPTIVE FORMS OF BEHAVIOR
Situation: Single String with Grill

The dropping out of the less adaptive forms of behavior is represented by the descending lines in Figure 6, which is a corollary to Figure 5. Here one may see what the infants were doing at 28 weeks instead of approaching and securing the string and pulling the lure in reach. The hands were frequently occupied with the grill, occasionally with the chair, clothing, or mouth, sometimes on the table top; there was considerable squirming in the chair, rocking back and forth, kicking and rubbing of the feet on the platform;

the regard shifted to the surroundings, away from the lure, table, and grill. Though hand activity on the table and in contact with side rail, platform, chair, mouth,[2] or clothing increased in frequency at 32 weeks, the general trend of the lines is downward. Fussing, it may be noted, tended to maintain a fairly constant level until 44 weeks, the age at which success was certain in all cases.

The matter of hand approach to the lure needs special comment. Possibly some of the activity on the grill was really approach to the remote lure. Definite extension of the hand toward the lure scarcely appeared, however, until 36 weeks, and then continued to occur only occasionally until 48 weeks, when it became rare. At least two factors may be mentioned as contributing to this phenomenon. At 28 and 32 weeks the grill was a barrier to approach. Later it became less of a barrier, but at this time the string rather than the lure was becoming the object of approach. The extent to which and the ways in which the grill served as a barrier will be considered in a later section.

A reduction in the time required to pull the lure in reach is another manifestation of development. The time records are presented here (Table 6) chiefly as a point of departure for discussion later on.

The median time required at each age is given in Table 6. The drop at 44 weeks in the median for all presentations is significant in relation to the peak in

[2]Mouthing of the hand or sucking of the fingers was less frequent than one might have expected. It is reported in only 6% of the presentations at 20 weeks; 9% at 32 weeks; 6% at 36 weeks; 2% at 40 weeks; and none thereafter.

TABLE 6

MEDIAN* TIME (SECONDS) REQUIRED TO PULL LURE IN REACH, CONTACT, OR SECURE

Age in weeks	28	32	36	40	44	48	52
Median of all presentations	not pulled in	not pulled in	not pulled in	55† (45)	20	15	12
Median of presentations where lure was pulled in reach	72	65	50† (45)	25† (25)	20	15	12

*Medians counted from actual scores, not calculated, except at 28 weeks.
†If Boys C and G at 36 weeks and Boys C, E, G, and J at 40 weeks had been given a repetition of the situation and had made the same record as in their first performances (see Table 7, p. 78), the medians would have been as indicated in parentheses.

adaptive behavior reached at that age. It is also worth noticing that if the median is based only on the presentations where the lure is pulled in reach, a similar drop occurs at 40 weeks. The development following 44 weeks, which could not appear in Figure 5, shows in the time medians.

Perfect accuracy is not claimed for the time records. In some of the early examinations or on especially trying occasions the time was not reported. Sometimes it then seemed possible to estimate the time from the behavior reported, by comparing it with similar behavior where the time was reported. These cases are indicated by interrogation marks in Table 7, which is given in a later section. If the time before the lure was pulled in reach was reported, that is the time given in the table. Sometimes, however, the only report is of the time until the lure was secured. In spite of these defects, the time records are included here because they do reveal significant trends.

Effect of the Grill on the Behavior

The results presented in the preceding section indicate that the grill played an important part in the situation even aside from its prevention of direct creeping or climbing over the table to secure the lure. Figure 6 showed that hand activity on the grill before pulling in the lure was conspicuous at 28 weeks and rare from 44 weeks on. The lack of clear approach to the lure at 28 and 32 weeks was referred to the obstruction offered by the grill. From Figure 5 one may read that the presence of the grill delayed pulling in of the lure about 8 or 10 weeks.

A further analysis is offered here to show more in detail the effect of the grill on the adaptive behavior and the factors which contributed to this effect.

Comparison of Behavior with Grill and without Grill at 28 and 32 Weeks. The obstructing effect of the grill was most noticeable at 28 and 32 weeks. At each of these ages 11 infants were given the opportunity to pull the lure in from the open table top because of their lack of success when the grill was in place. The adaptive behavior of these 11 infants in the two types of situations is compared in Figure 7. In every respect except in regard for the lure there was a reduction in adaptive behavior when the grill was in place. Except in the case of regard for the string and contact with the string this reduction, if measured by subtracting the length of Column *a* from *b* and *c* from *d*, was greater at 32 weeks than at 28. This should not be taken to mean, however, that the grill was more of a barrier at 32 weeks than it was at

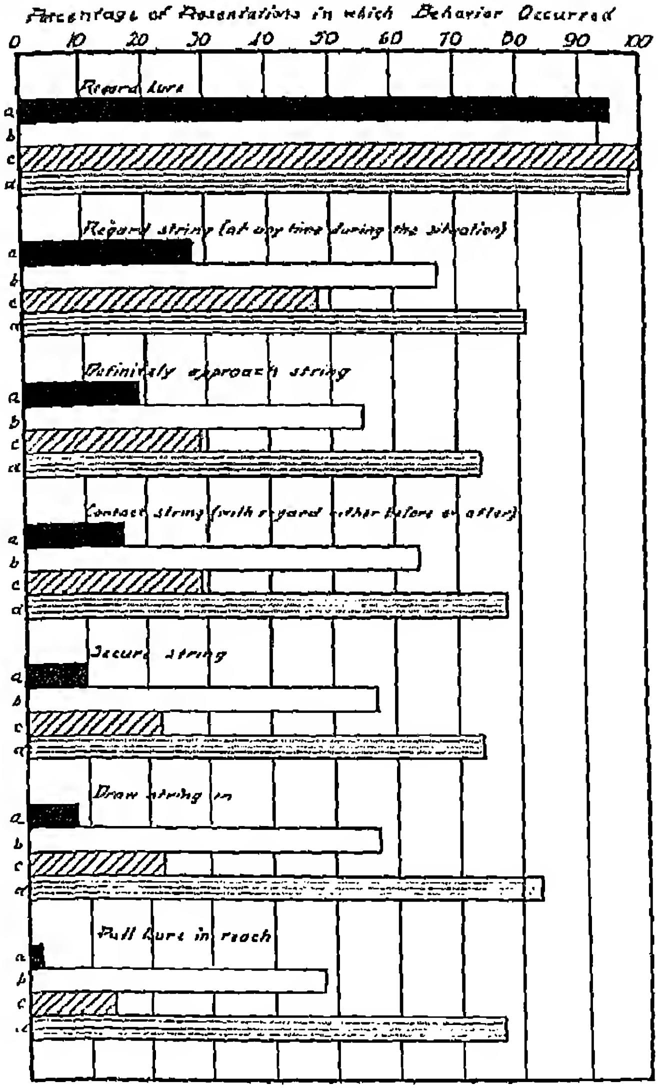

FIGURE 7

ADAPTIVE BEHAVIOR WITH GRILL AND WITHOUT GRILL

a—28 weeks, with grill; *b*—28 weeks, without grill; *c*—32 weeks, with grill; *d*—32 weeks, without grill.

28 weeks, for the difference between Columns *b* and *c* is less than the difference between *b* and *a*. Furthermore, if Boys B and G, successful with the grill at 32 weeks, were also part of this group, the difference at 32 weeks would appear less than it does in this graph.

Certain peculiarities in the columns representing behavior without the grill need comment. Approach to the string, in the sense of a

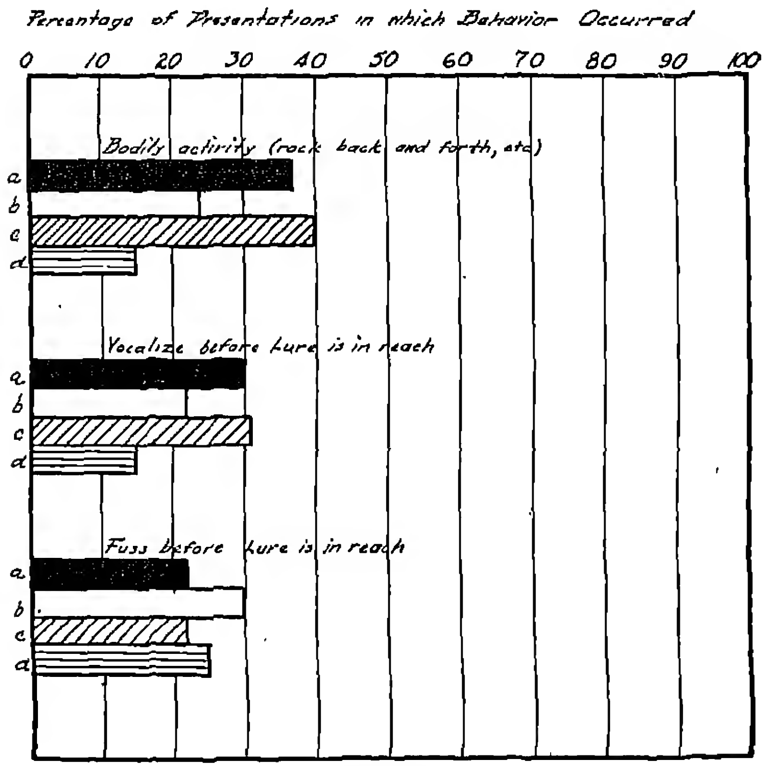

FIGURE 8

Collateral Behavior with Grill and without Grill Before Lure Is in Reach

a—28 weeks, with grill; *b*—28 weeks, without grill; *c*—32 weeks, with grill; *d*—32 weeks, without grill.

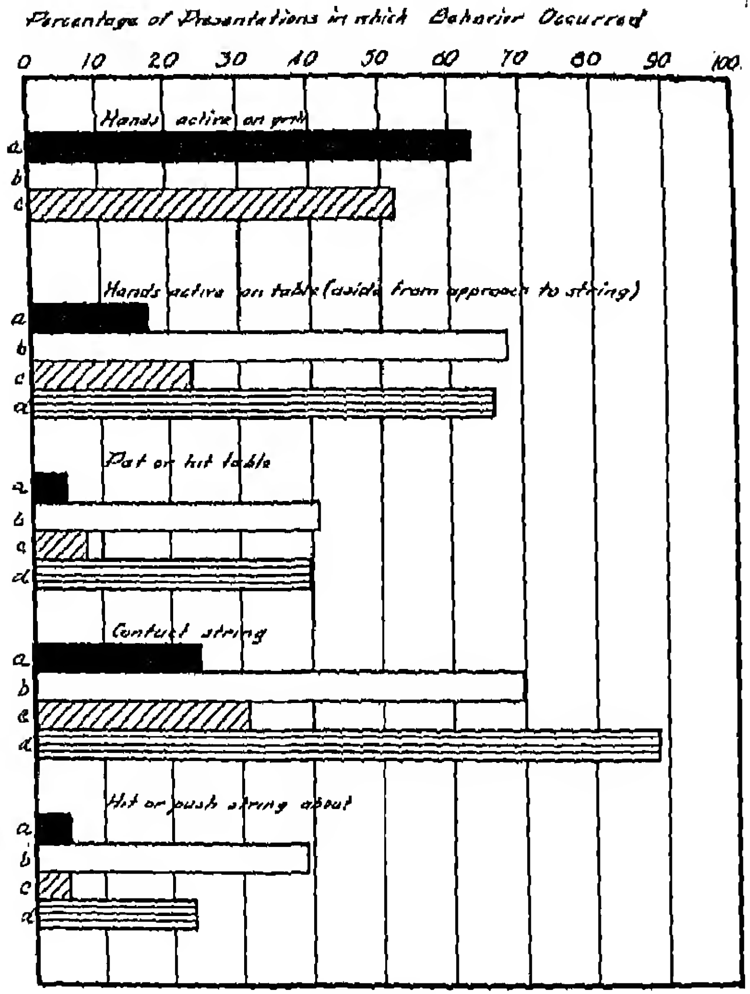

FIGURE 9

THE GRILL AS A MECHANICAL BARRIER

a—28 weeks, with grill; *b*—28 weeks, without grill; *c*—32 weeks, with grill; *d*—32 weeks, without grill.

definite movement toward the string, accompanied or preceded by regard, was less common than contact with the string in which the regard for the string might come only after a fortuitous encounter and might fail to be followed up. Drawing in of the string might occur more frequently than regardful contact or securing of the string: by straining and patting across the table top in the direction of the lure the infant might drag the string in without grasping it or giving evidence of regard for it.

At the same time that the grill reduced the adaptive behavior it increased the amount of vocalization and restless, unfocalized bodily activity (Figure 8).

Nature of the Obstruction to Adaptive Behavior Offered by the Grill. The obstruction offered by the grill appears to have been *both mechanical and visual* in nature. Figure 9 presents evidence that the grill was a *mechanical* barrier. When the grill was in place the hand activity was mainly on the grill and there was relatively little of the activity on the table top which was a leading feature of the behavior when the grill was absent. This activity, frequently a patting or hitting of the table top, may very reasonably be held responsible for at least part of the additional contacts with the string. The hitting or pushing about of the string sometimes brought it into a position where it could more easily be secured. Though this activity on the table top might be called "less adaptive" in the sense that it was not the most economical method of bringing the lure in reach, it undoubtedly helped to produce successes at 28 and 32 weeks.

The studies of infant prehension by Halverson (16) suggest a more fundamental explanation as to the way in which the grill keeps the infant's hands from the string. In an analysis of cinema records of the ap-

proach made to a one-inch cube, 6 inches in front of the infant on a table top, he found a "circuitous" type of approach in about three-fourths of the cases at 36 weeks, a "straight" approach gaining a slight pre-

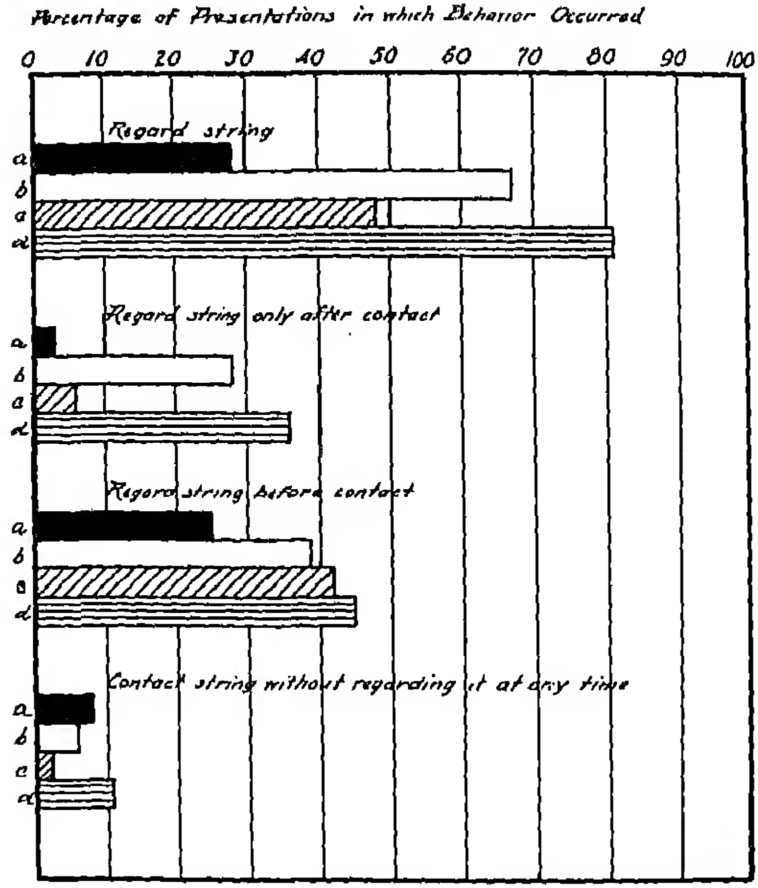

FIGURE 10

THE GRILL AS A VISUAL BARRIER

a—28 weeks, with grill; *b*—28 weeks, without grill; *c*—32 weeks, with grill; *d*—32 weeks, without grill.

ference at 40 weeks and occurring in about nine-tenths of the cases at 52 weeks. Preliminary results from a later study by the same investigator show that in another group of average infants at 44 weeks about seven-tenths of the approaches were straight or almost straight, and at 48 weeks about nine-tenths. A grill with vertical bars 3 inches apart obviously must be a barrier to securing of the string, even close to the table edge, as long as the characteristic approach is circuitous.

Some evidence that the grill was a *visual* as well as a mechanical barrier appears in Figure 10. (*a*) The string was regarded much more frequently on the open table top than behind the grill. (*b*) To be sure, considerable of this was regard that came only after the contact that was permitted by the greater freedom of approach. (*c*) But even before the string was contacted it received more frequent regard in the absence of the grill. (*d*) At 28 weeks, though the number of contacts with the string was very small when the grill was in place, there were more contacts without regard under those conditions. The reversal of this relation at 32 weeks seems to be traceable to a certain intensification of interest in the lure to the exclusion of the string displayed by a few infants in the presentations without the grill.

It might be expected that the grill would be an emotional barrier, but the analysis of the protocols reveals that there was fussing in a slightly smaller percentage of presentations when the grill was present. This may be because the presentations without the grill always

came later in the examination. Fussing increased in frequency as the examination period progressed. When all the presentations both with and without the grill at both 28 and 32 weeks are combined, the percentage for which fussing is reported before the lever situation is 16; after the lever situation, 37. Fatigue and thwarting are probably cooperating and interacting causes.

The question may be raised whether the grill was an obstruction or a distraction. Probably it was both. The data do not decisively answer the question.

Additional comparisons of behavior with and without the grill form part of a later section (p. 270).

Development in the Motor Capacity for Prehension and Pulling of the String

The preceding section made it clear that a remote objective behind a grill with an attached string coming to the grill confronts the infant with problems that are motor as well as intellectual. Other mechanical problems besides getting through the grill to the string are the prehension and the pulling of the string. Both of these problems, like the problem of approach, are matters that require cinema analysis for thorough investigation. The behavior records of the present experiment, however, present some data which show that growth brings to the infant an increasing capacity to cope with these problems.

The development of proficiency in prehension is suggested by the diminishing ratio which reported difficulty in securing the string bears to the percentage of

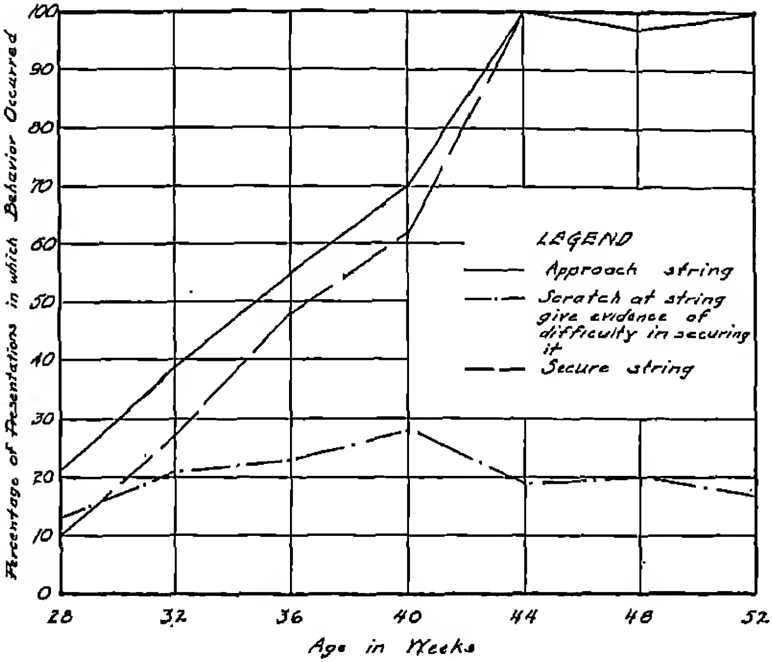

FIGURE 11
DEVELOPMENT OF PROFICIENCY IN PREHENSION
Situation: Single String with Grill

presentations in which the string is approached and secured (Figure 11). This difficulty might not persist, even to such a minor extent, through 48 and 52 weeks if the infant were picking up a simple string with no lure in the distance to compel the regard. The ease of prehension of the string probably is in part a function of perceptive attitude.

The string was sometimes pulled in by raising the hand, sometimes by drawing the hand back and out at the side, sometimes by an intermediate method. Some-

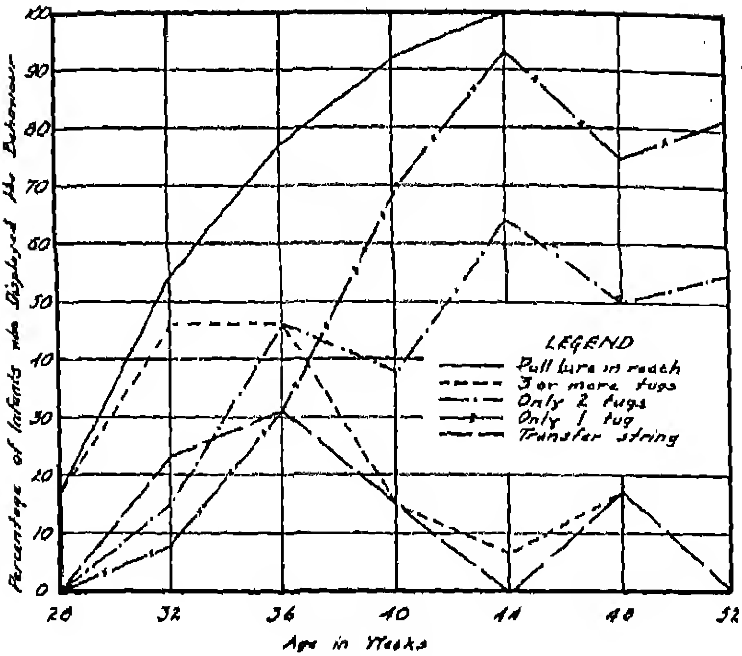

FIGURE 12

DEVELOPMENT OF PROFICIENCY IN PULLING THE STRING

Situation: Single String with Grill

times it was jerked by waving the hand. Sometimes the hand holding the string was waved but the amount of slack in the string prevented movement of the lure. The frequencies of these several types are not given because, although they are occasionally mentioned in the protocols, too often it is simply stated that the "string is pulled."

One matter that seems to have been reported consistently enough to be represented in a graph is the transfer of the string from one hand to the other in connection with pulling it in. The percentage of in-

fants who transferred the string from one hand to the other is shown in Figure 12. The ratio of such cases to the total number who pulled the lure in reach decreases after 32 weeks.

To bring to the edge of the table an object that is distant by 18 inches of string can be accomplished with a single arm movement only if that movement is rather large and free. Analysis of the behavior records reveals that sometimes three or more separate tugs were necessary to bring the lure in reach. A "tug" is here considered to be a unitary movement made by the hand grasping the string, a movement that has a rather definite beginning and end and that brings the lure nearer to the child. One speaks of a tug only if the string is actually grasped; therefore this concept is not applicable to certain cases in the situation without the grill. Figure 12 shows what percentage of the infants at each age brought the lure in grasping reach with only one tug, what percentage used only two tugs, what percentage three or more. These percentages are to be considered in relation to the percentage of infants who pulled the lure in reach. Since a given infant in a given examination might on one occasion employ only one tug and in another presentation might give two tugs, the sum of the percentages of each type usually amounts to more than the total percentage of infants who pulled the lure in reach. The percentages are given in terms of infants rather than presentations because of the number of individual presentations where the protocols leave the matter uncertain. Crude as the data are, the lines show significant trends. The

matter of the number of tugs is, of course, not wholly a question of motor capacity. The infant who is more definitely and eagerly using the string to gain the lure may give one swift tug. The greater number of tugs at the earlier ages may be due in part to hesitation and perceptive uncertainty. The one infant who gave four tugs at 48 weeks was just at that time in a somewhat negative attitude toward the examination.

Types of Perceptive Attitude as the String Is Secured and the Lure Is Pulled in Reach

Five Types of Perceptive Attitude. On the basis of differences in the total pattern of regard and hand activity during the securing of the string and the drawing in reach of the lure, it seems possible to infer five types of perceptive attitude representing different levels of maturity.

These are not directly observable behavior items such as were treated in the three preceding sections, but are the result of a logical, interpretative method of dealing with the material.

The five types are listed below, arranged roughly in the order of maturity level that they represent.

Type a. Interest in the string. The string is fingered or carried to the mouth. The lure comes in reach and is then secured.

Type b. Interest in the lure, apparently without awareness of the string. The hand straining toward the lure may move the string sufficiently to drag the lure in reach. If the fingers close over the string, it seems to be on tactual cue.

Type c. Apparent awareness of both string and

lure at the time of pulling in the lure, but no clearly purposive utilization of the string unless on occasions where the string is finally grasped two or three inches from the lure.

Type d. Experimentation, watching the results of a movement of the hand that holds the string. The function of the string may seem to be discovered in the act of pulling.

Type e. Definite utilization of the string as a means to bring the lure in reach. The infant regards the lure and promptly reaches for the string, with or without obvious regard for the latter. Often it is specifically stated that he looks at the lure as the pull begins. (In this class are included a few cases where the reaching was delayed apparently because the string was not seen at first, but promptly followed on sight of the string.)

The term "insight" in the sense of awareness of the means to an end might be used with reference to these types of perceptive attitude. One may say that in *a* and *b* there is success without insight; in *c* and *d* success with partial or gradual insight (insight incomplete but dawning); in *e* success with definite insight.

A given performance does not necessarily embody one type alone, but may show characteristics of two or more: of *a, c,* and *d,* for example. Often it is hard to draw the line between types, especially between *c* and *d.* Some of the performances classed as Type *d* may actually be Type *e* with the behavior modified by motor difficulty in pulling the string. One infant does not necessarily display all five types in successive examinations.

Illustration of These Types from the Protocols. Boy C in his one success at 28 weeks exemplified Type *a*, with a suggestion of *c* at the end. At 36 weeks he is given credit for Type *e*. Further illustrations of all the above types except *b* may be found in the following quotations from the protocols of Girl B and Boy G. These records also present a number of other peculiarities that are instructive, and illustrate the difficulties presented by the material.

Girl B. 28 weeks. Without grill. M1. Type a. 80 seconds. She looks at the cat, leans over a little to the left, looks at the cat again. Her right hand becomes engaged with the string. She prehends it with her right hand. Looks at the cat; looks at the string. She becomes concerned with exploring the string with both right and left hands rather than looking at the cat. She gets the string up higher in her left hand; cat moves in slightly. After 55 seconds she releases string; looks at cat; pats table with right hand; then becomes interested in the string again. Picks it up in her right hand; scratches the chair with her left hand; then turns in the direction of the Examiner and raises her right hand, releasing string. After 1 minute and 20 seconds gaze returns to cat, which is now in reach, and she grasps it.

One hardly feels that this can be called success, since there is so little effort directed toward the lure.

Girl B. 32 weeks. Without grill. L1. Types a and c. 90 seconds. B looks at the cat, then pats the table top with her right hand, looking at the table and off to the left. She leans forward and apparently looks at the string. She puts her right hand on the string and brings her thumb and fingers together, raises her hand without the string and looks at it as if perhaps thinking she had picked up the string. She brings her right hand back on the table; puts her left hand on the string near the edge of the table. (Her right hand had been about half way along the string.) After some time she picks up the string with her left hand, looks at it, and pulls it in a little way; with a second pull she brings it in farther. She notices

the cat moving in, gives another tug to the string, waves her right hand, brings her right and left hand over to the cat. She pulls the cat a little closer in, places her right hand on it, and pats it.

This additional tug to the string is counted as Type *c* rather than *d,* since it might have been simply a jerk of the left hand, which held the string, similar to the wave of the right hand which is mentioned at about the same time.

Girl B. 36 weeks. Without grill. R1. Type d. 100 seconds. B immediately brings her left hand down on the table top and pats it. The roly-poly doll is rocked by the Examiner. B looks at it steadily for several seconds, looks at the Examiner and pats the table with her right hand, also with her left. Her right hand is near the string but she does not touch the string. She looks back at the doll; leans forward, placing her right hand on the string. She looks at the doll, then looks at the string. She opens and closes the fingers of her right hand on the string. She picks it up in her right hand, looks at the doll as it begins to move in. She drops the string, looks back at the doll, picks up the string again closer to the doll. She takes the string in her right hand. The doll, as she pulls it, rocks so that the head is almost within reach. B tries to reach it but the head rocks out of reach. She picks up the string, gives a little pull which rocks the doll. She tries to reach it again but it rocks out of reach. She vocalizes, leans forward and again takes the string in her right hand. She brings the doll within reach and carries it to her mouth.

Same. L1. Type e. 8 seconds. B leans forward immediately. While looking at the doll, she puts her left hand on the string and quickly picks it up. In 8 seconds she has secured the doll. She knocks it on the table with her left hand.

Unfortunately, there is no good check on the permanence of this achievement at 36 weeks. During the lever situation B began to cry, and during the succeeding string situations with the grill in place she cried readily and did not try to pick up the lure even when the Examiner moved it to the very edge of the

table. When the grill was removed, she still cried when confronted with a new lure with the string at the right. After 35 seconds the Examiner moved the string to the left when B was apparently not looking. B stopped crying, put her left hand on the string, picked it up, pulled the lure to the edge of the table, and contacted it within 8 seconds. Since the procedure was questionable here, this presentation probably should not be given equal status with the others. Yet, even if the Examiner's movements were what called B's attention to the string, the prompt utilization of the string suggests that it was a genuine means to an end. The string must be noticed if it is to be adaptively utilized.

Girl B, 40 weeks. With grill. R1. Type e with delayed regard for string. 67 seconds. B is looking at the cat already when the Examiner squeaks it. She reaches with her right hand through Space 5*A*, with her left hand as far as she can through Space 4*A*. Her left hand is pronated on the table. She looks at the cat and occasionally at the Examiner. She is looking rather prolongedly at the cat. She looks over to the right side rail. After 47 seconds she is noted to look at the string; picks it up by the end between the thumb and first finger of her right hand, with rather precise prehension. She draws the string back rather slowly, watching the cat come in. One minute 7 seconds after the situation was instituted she has secured the cat.

Same. L1. Failure. She stops fussing immediately and looks at the cat. She is leaning a little to the left. She looks over to the right side of the table (where the string was before). With her right hand through Space 6*A* she reaches towards the cat. She looks up at the ceiling on the right. She begins to cry. She looks back at the cat, looks at the Examiner and looks up at the right. She cries. Her left hand contacts the string as she reaches through the grill but she does not look at it. She quiets when the cat is squeaked but begins crying again.

The tendency to look in the direction where the string was before, and the emotional upset due to thwarting seem to be responsible for the failure. The fussing at removal of the lure just before this presentation may have been the first disturbing factor. After the lever situation, in *R2*, B was crying again, but at the sight of the string her fussing "trailed off" and she pulled the lure in reach. In *L2* and *M2* she gave no evidence of seeing the string, and cried loudly. After this, even when the grill was removed, she paid no attention to the string on the left.

By 44 weeks Type *e* appeared in all the presentations with the grill in place. Though 105 seconds altogether were required for the first presentation on the right, the time after the string was regarded and approached was only 15 seconds. Table 7 shows the reduction in time in the remaining presentations. At 48 and 52 weeks Girl B showed a similar delay in her regard for the string on the right, but her performances were distinctly of Type *e*.

Reference to Table 7 shows that Girl B is fairly representative of the girls in her achievement with the single string. Boy G, part of whose record follows, is fairly representative of the boys.

Boy G. 28 weeks. Without grill. L1. Type a with more awareness of the approaching lure than was displayed by Girl B. Counted as Type a with a suggestion of c. 60 seconds. G looks at cat, leaning forward. His left hand is on the string but he does not look at it. After about 20 seconds he seems to be rather eagerly stretching towards the cat. He looks down at the string, pats the string, looks at the cat. He secures the string between his thumb and all the fingers of his right hand, carries it to his mouth, 50 seconds after the situation was instituted. This movement drags the cat half way

across the table so that by leaning forward he picks it up one minute after the beginning of the situation.

Boy G. 32 weeks. With grill. R1. Type d. 65 seconds. G is leaning over to the right, scratching blotter. When the cat is squeaked, he looks at it. Leans forward, regarding it intently. Pulls himself closer so that his face is close to the grill. After 25 seconds, he looks at the string on the right. Scratches at it a little. Picks it up in his right hand. Draws right hand back to side. One tug brings cat half way across table. Another tug pulls it an inch farther. Releases string putting it over Bar *A*. Looks at cat for a few seconds. Picks up string. Watches cat come in after one minute. Has secured it and pulled it through grill 5 seconds later.

Transposition of the string to the left now seemed to make the problem insoluble to Boy G, as it did for Girl B at 40 weeks, but the response to the thwarting was of a different type. Boy G regarded the lure for about 25 seconds, twice turning to look at the Examiner. Then he rocked back and forth in the chair, repeatedly looked down and scratched the blotter, and finally extended his left hand toward the Examiner. It was never certain that he looked at the string, though once his left hand came in contact with it. This scratching of the blotter appears in numerous other cases where the infant seems to be at a loss, and may be a compensatory activity.

Same. M1. Type d complicated with motor difficulty. Might have been Type e. 60 seconds. Gaze goes to cat when squeaked. Looks from cat down to string. Index finger of right hand scratches at the string. Secures it with all of his fingers and his thumb. With one slow tug he draws cat to within about 4 inches of the edge of the table. Drops string, but picks it up again. He draws right hand back and waves it, but cat moves no farther in. Extends hand toward cat. Picks up the string again in his right hand; holding the string, he pats hand up and down on lower frame of grill. After one minute he has drawn cat to where he contacts it. Pushes it

almost out of reach, but gets it by the tail between the tips of the fingers of left hand and draws it through grill.

Same. R2. Type e? 50 seconds. Squeaking of the cat brings his attention to it. Looks from cat, after 10 seconds, to the string on the right. Scratches on the string. Looks from string to cat and back to string. Picks up the string, looking at the cat. Drops string. Extends right hand through Space *5A* towards cat, but does not secure cat. Secures string in right hand. Draws cat to where he contacts it.

Same. L2. Failure. Looks at cat and smiles a little. Looks toward right, then back at the cat and smiles again. Leans forward looking at the cat. He is picking at the chair on the right. Looks back at the cat, down to the right side of the table, leans to the right side rail, and starts to pull himself toward it. Looks back at the cat. After 45 seconds he catches sight of the string on the left. Scratching on it with left hand, looks from string back to the cat. Then looks again at the string as he tries to prehend it. String gets pushed out of reach and is moved back to position by Examiner. Looks at the cat. Looks to left side rail, then to right. Leans over and scratches blotter on the left. Looks at the cat and vocalizes, "baa baa." Examiner squeaks the cat again. G looks at it. Rocks himself back and forth in the chair, holding onto Bar *A* with both hands. Rocks very vigorously.

Same. M2. Type c? Failure. Motor difficulty leads to an inferior type of behavior. G looks at duck. Looks at the Examiner. After about 15 seconds he looks at the string. Immediately left hand approaches it and pushes it around on the table. He picks it up. Duck tips over. He watches duck come in. Two tugs bring duck to about 6 inches from edge of table. Leans forward, straining with left hand toward duck. He touches it and pushes it farther out of reach so that he cannot contact it. Strains for it persistently. Although his fingers are close to the string, they do not close over the string. Now he seems to have lost interest in the duck. Waves his arms, vocalizing. Extends left hand toward Examiner, smiling. Leans over to platform on the left.

At 36 weeks Boy G, like Girl B at 44 weeks, was successful in both right and left positions, with a perceptive attitude of Type *e*. A presentation with the cat as lure which seemed to arouse little interest and no evi-

dent regard for the string was followed by the behavior described below.

Boy G. 36 weeks. With grill. L1. Type c with delayed regard for string. 90 seconds. Fish is rattled. G looks at it. Looks up at the ceiling. His gaze comes down to the fish. Glances in the direction of the Examiner. Back to fish. Tips himself up to the grill. Begins looking around the room. Fish is rattled again. Looks back at it. Tips himself forward in chair again. Once his left hand goes through Space 3*B* in direction of the fish, but it is withdrawn. Looks over to right side rail. Reaches for it. Looks down on the table top and pokes at one of the letters on it. After 1 minute 15 seconds he looks at the string. Secures it in his left hand. Looks from string to the fish as he picks up the string. Draws his left hand back and with one tug brings fish to where he contacts it 1 minute 30 seconds after the beginning of the situation.

Same. R1. Type c. 30 seconds. Note the initial looking toward left, where string was before. He looks from fish over to left side of table, then looks over to the right side and sees the string. Begins scratching on the string, looking from string to fish. Draws back right hand after securing the string. Has dragged the fish through Space 6*A* onto the platform 30 seconds after the beginning of the situation.

Successes with a perceptive attitude of Type *b* are illustrated in the protocol of Boy E at 32 weeks in the situation without the grill. Increasing awareness of the string appears in the successive presentations.

Boy E. 32 weeks. Without grill. R1. Type b. 70 seconds. E looks intently at the duck and brings his right hand up on the table. His hand falls on the string. As he moves his hand in, the string adheres to his fingers and moves in a little. He does not seem to notice the string. Later, as he is leaning forward, raising himself somewhat from the platform, his right hand is resting on the string and moves the string a little. As he is regarding the duck, he drags his right hand back a little, and the duck moves in slightly. He looks at the string now. Then he strains forward over the table top trying to reach the duck. His head approaches as well as his hand. He does not take hold of the string to pull in the duck, but

as his arm is resting on the string it is dragged back and the duck is brought within reach. He secures it.

Same. L1. Types b and c. 70 seconds? E leans forward raising himself from the platform and extending his head toward the duck. At first his hands are out at the side of the table; then his right hand comes forward and he looks at it. His gaze comes down to the string once, although he has been looking at the duck during most of this time. He makes as if to prehend the string once as his right hand rests on it. The thumb and first finger come together but he does not secure it. As he looks at the duck, his hand which is resting on the string moves in, thus causing the duck to come in a little. One minute after the situation was instituted, he secures the string more definitely in his right hand, and as he draws his right hand back, the duck moves within reach. He immediately brings his hands to it.

Same. R2. Motor difficulty. E leans forward immediately in the direction of the cat and scratches the table top. He looks at the cat, looks at the string on the right. He brings his fingers together over the string and holds them up, looking at them as if he had the string in them. Again he opens and closes his hands over the string. He finally prehends it between the thumb and forefinger. As he draws his hand back, the cat moves in a little and falls over. He drops the string, looks back at the cat; then he takes hold of the string again in his left hand and draws his hand back a little but not enough to move the cat in. He releases the string and reaches directly for the cat. He wriggles considerably. He looks at the Examiner, looks back at the string. He begins to suck his hand. His vocalizations sound a little fussy. He looks at the Examiner and draws his hand over the string again but it does not come in. His hand opens and closes over the string when he is not looking at it. His vocalizations are fussy. He rocks back and forth looking at the cat. He turns to the left. He is breathing hard. The Examiner squeaks the cat again. He looks at it, makes a little vocalization, and turns again to the left waving his left hand. He takes hold of the rods of the left side panel and starts to pull himself over. He lets go and leans over to the platform on the left. He scratches the table top on the front left corner with his left hand. After 3 minutes he seems not to be attentive to the cat, but rather to the side of the crib.

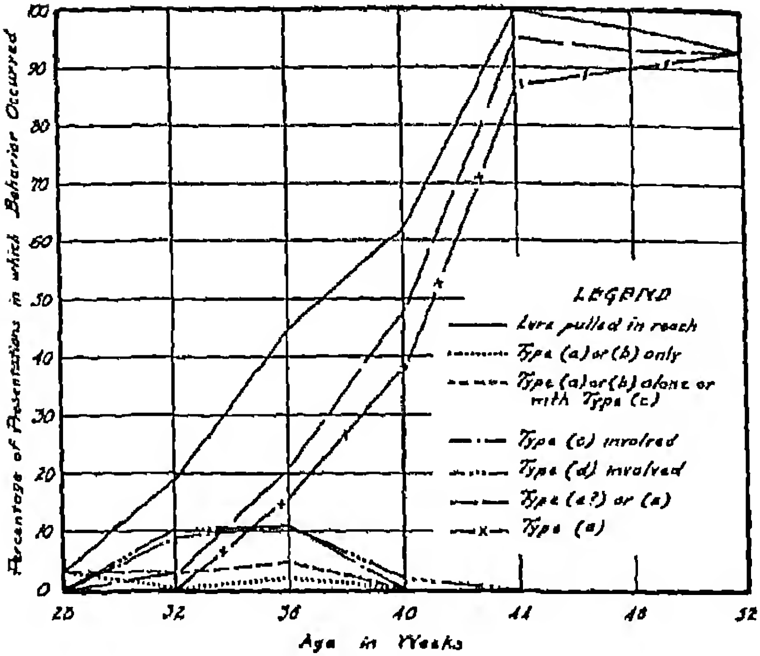

FIGURE 13

APPARENT PERCEPTIVE ATTITUDE AS THE STRING IS SECURED AND THE LURE IS PULLED IN REACH

Situation: Single String with Grill

Age Distribution of These Perceptive Types in the Situations with the Grill and without the Grill. In the foregoing illustrations, one notices that examples of success with the lower types of perceptive attitude have been drawn from the situation without the grill. Figures 13 and 14 show that this distribution is characteristic of the group as a whole. After the two successes with the grill at 28 weeks, both of which were of Type *a*, there was only one example of a pure Type *a* and no instance of a pure Type *b*. By the time that

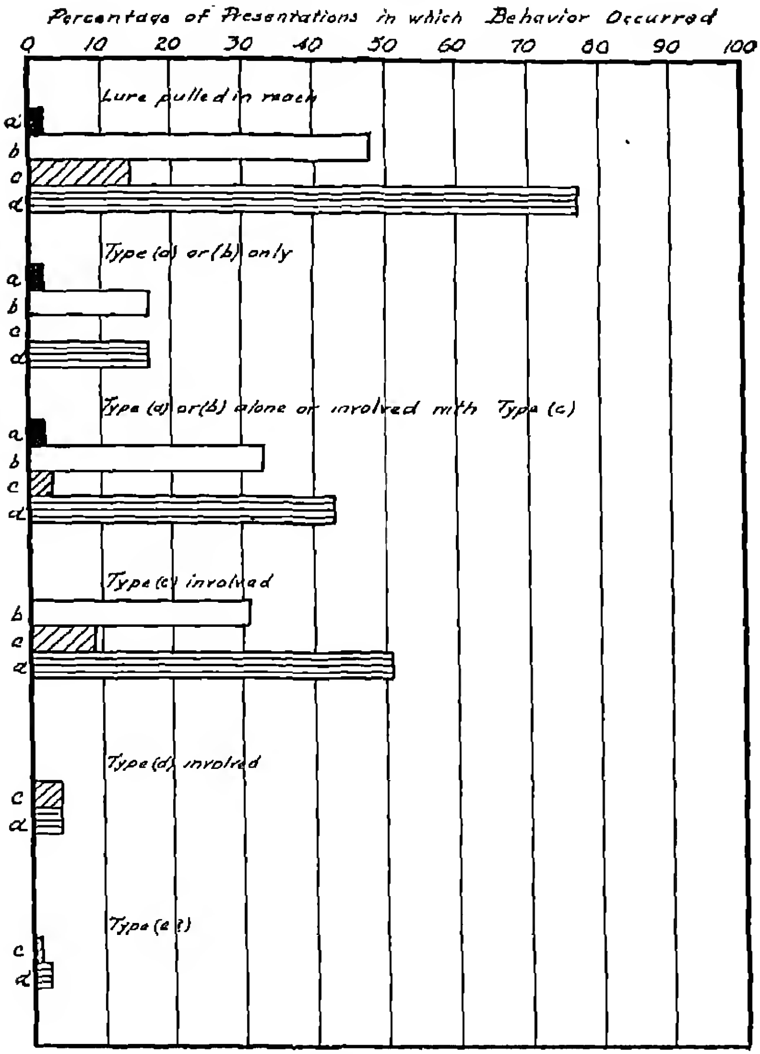

FIGURE 14

APPARENT PERCEPTIVE ATTITUDE AS THE STRING IS SECURED AND THE LURE IS PULLED IN REACH

Comparison of situations with and without grill

a—28 weeks, with grill; *b*—28 weeks, without grill; *c*—32 weeks, with grill; *d*—32 weeks, without grill.

successes with the grill were of more than 50% frequency, they were almost entirely of Type *e*, or closely approached that type, in all the cases where the interest in the lure appeared to be adequate and where the records are complete enough to permit judgment. On the other hand, the open table top permitted a considerable proportion of successes of Types *a* and *b*, either alone or involved with a suggestion of Type *c*. At 32 weeks the proportion of Type *c* to total successes is approximately equal for the two kinds of situation; in Types *d* and *e*, the grill situation scores a larger relative number.

Critical Discussion of Development in Perceptive Attitude. From the relation between type of perceptive attitude and success in the two kinds of situation, one may conclude that perceptive capacity and motor capacity to overcome the difficulties offered by the grill are developing together. With the open table top, motor capacity may be in advance of perceptive maturity. With the grill in place, perception may at times seem to be in advance of motor ability, as in the case of Boy G at 32 weeks.

The question of perception *versus* motor capacity with the open table top needs some further consideration. The case of Boy E quoted above (*R2*) suggests that definite pulling in of the string offers a more difficult mechanical problem than getting the lure in reach by straining forward and fortuitously moving the string. Boy E's perception here appears to be in advance of his motor capacity. It is also likely that definite pulling is more difficult than producing a

movement of the lure by fingering the string and carrying it to the mouth.

The difficulty of drawing lines between complete insight, partial insight, and lack of insight is evident from the examples of behavior that have been given. Even in the performance of Girl B at 28 weeks, classified as Type *a,* there is a possibility of fleeting moments of awareness of lure and string in relation to each other, and the same is true of Boy E at 32 weeks in the performance classified as Type *b*. In the Type *d* behavior of Boy G at 32 weeks we had to admit the possibility that the behavior actually was of Type *e* but modified by the motor difficulty.

Even after the appearance of successes that seem to be of a high perceptive type, further development may be needed before there is sufficient flexibility to permit success when the string appears in a new position. Flexibility of perceptive attitude is lacking when the string seems not even to be regarded in its changed location (Girl B, 40 weeks, *L1;* Boy G, 32 weeks, *L1*). We might say that here the infant has been using not simply "string," but "string on the right," though we do not mean to imply that the analysis is on precisely such an ideational level. It seems to be "string on the right" rather than merely "the right," since the infant does not persist in activity centered about the place where the string previously was. [See the case of Boy C at 48 weeks (p. 282), for evidence that there is a definite expectation of finding the string in its former location.]

Similar evidence of degrees of insight has been

found by other investigators. Ruger (27, p. 11) calls attention to the mere observation of the portion of the puzzle to be attacked as a "low grade of analysis." Our cases of "lack of flexibility" bear a resemblance to such "locus" analysis, though they are not entirely parallel. Koffka (19, p. 279) calls attention to "anticipations" and refers (19, p. 213) to "the first weak pushes" which Köhler's youngest ape, Koko, gave in the box experiment (20, p. 41) as evidence that "the connection between the box and the goal was beginning to 'dawn.'" Alpert (2, p. 67) speaks of "the unstable nature of insight" and enumerates cases of problem-solving accompanied by partial insight. Wyatt (37, p. 377), after his analysis of Ruger's and Peterson's experiments, concludes that "the act of insight . . . . is often a succession of glimmering apprehensions, and is found in all degrees from elusive and indefinite dimness to a clear and convincing definiteness."

In the case of infants the ambiguous, imperfect, spasmodic cases seem to give evidence that the maturity level is not quite adequate to the problem. Every infant eventually reaches a stage after which he is always successful in this simple problem and his successes seem to be consistently of Type *e*. Shall we say that by this time he has "learned" the use of the string? The study of identical infant twins by Gesell and Thompson (12) shows that general maturation is more important than specific experience in the development of stair-climbing and manipulation of cubes. Undoubtedly, gross motor and fine motor development, maturation of the nervous system, develop-

ment of visual span, and the effects of previous experience are all involved. It must be when all these are adequate that we find the instances of sudden change in perceptive attitude developing within a given examination and consistently followed by successes of a high type. Boy G at 36 weeks and Girl B at 44 weeks are examples. A more striking case is that of Boy F at 36 weeks, which will be presented in the next section (pp. 286 ff.). In the case of Boy F the change seemed to come first from observation of the result of a rather fortuitous encounter with the string, but the observation of a very slight "chance-produced" movement was followed by a rather definite and effective tug, and the new attitude persisted when the string appeared in a different position. In the case of Boy G and Girl B, catching sight of the string seemed to change the aspect of the situation.

Of course, in such cases as those of Boy G and Girl B one need not assume that there is more than a *relatively* new perception of relationships. Boy G at 32 weeks had shown distinct approaches to a performance of Type *e*. The situation at 36 weeks, however, presented the problem afresh, and time was required to see the elements in relation to each other again. Girl B, in fact, seemed to need to discover the string anew at the beginning of each successive examination. Even though many of these infants (including Girl B but not Boy F) at home had objects with attached strings to play with, the exact visual pattern presented by the examination was probably never encountered outside. Though the behavior in the Multiple-Strings Situa-

tions sometimes shows the development of rather specific habit trends, the first right-hand and the first left-hand presentation of the Single String may be considered relatively new problems, particularly at 36 weeks. The failures to see the string in a changed location indicate that the lure with the string on the left is a new problem.

Though the perception of relationships occurring here may be only relatively new, nevertheless, it is new. Do not problems vary in difficulty in part according to the novelty of the perception that they demand?

Analysis of Time Records in Relation to Perceptive Attitude. The fact that Ruger (27, p. 50), Thorndike (34, pp. 189-191), and Bingham (3, p. 44) speak of the relation between insight and variations in the solution-time suggests an analysis of the time records in relation to perceptive attitude. Adams (1, p. 93) seriously questions the validity of the time criterion in animal experimentation, since the total time from beginning to solution is frequently lengthened by periods of inactivity and apparent indifference to the objective. It may be true that the presence of a sudden reduction in time score is evidence for a marked advance of insight. Occasionally in our experiment a lengthening of the time seemed actually to be conditioned by an advance in perceptive attitude, as in the failure of Boy E at 32 weeks (p. 269), but this was noted with an advance from Type *a* or *b* to *c* rather than with advance to Type *e*. Bingham (3) comments on the "rise occasioned by exploratory interruptions of consistent pro-

cedures." This phenomenon also appears in some of Ruger's curves (27, p. 65).

Our group medians for time required in the situation with grill show a rather abrupt drop between 36 and 40 weeks in the presentations where the lure was pulled in reach, and a similar drop between 40 and 44 weeks for all the presentations. To be sure, the time is determined by motor capacity to a considerable extent. This is the period in which the characteristic mode of hand approach to an object changes from circuitous to straight (Halverson, 16). The number of tugs used to pull the lure in reach becomes characteristically one or two instead of three or more (Figure 12). That a rather sharp change in perceptive attitude is also taking place, however, appears in Figure 13. Between 36 and 40 weeks the successes of other types than *e* or *e?* almost entirely drop out, and all cases where there is success approximate Type *e* in the records that permit any sort of decision on this point.

We now proceed to an examination of the time records in individual cases, confining ourselves to the situation with grill unless otherwise stated.

We have already quoted two instances of reduction in time score following activity of Type *e,* although we have also noted instances where successes of Type *e* were followed by failure when the position of the string was changed. Reference to Table 7 reveals certain significant periods in the record of each subject who was followed all the way from 36 through 44 weeks. The type of perceptive attitude through these periods will be considered in each case, with frequent quotations from the protocols.

Infant	28 weeks R1	L1	M1	R2	L2	M2	32 weeks R1	L1	M1	R2	L2	M2	36 weeks R1	L1	M1	R2	L2	M2	40 weeks R1	L1	M1	R2	L2	M2	44 weeks R1	L1	R2	L2	48 weeks R1	L1	R2	L2	52 weeks R1	L1	R2	L2
Boy A																									10 e	10 x	10? e	10? e	15 e	30 e			13 e	15 e		
Boy B	—	—	—	—	—	—	—	60 d	100 d	—	—	25? x	50 e	50? d		55 d	30 e		22 e?	8 e?		8 e?	25 e?		8? e	20? e	15? x	5 e	8 e	10 e			30 e	15 e	12 e	20 e
Boy C	—	—	—	—	—	—	—	—	105 acd	90 cd?	—	35? e?	—	25 e	30 e				13 e	45 e					15 e	20? e	55 e	55 e	27 e	—	8 e	8 e	8 e	10 e	10 e	15 e
Boy D	—	—	100 a	—	—								—	—	245 c	120 c	46 c?		(2) 45 e	(1) 35 e		—	30 e		22 e	15 e	25 e	22 e	10 e	10 e			10 e	3 e		
Boy E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	80 bc	—	123 c	60 e	20 e					20 e	180 e	15 e	7 x								
Boy F	—	—	—	—	—	—	—	—	—	70	—		—	—	—	(2) 30 d	(3) 18 e	(1) 25 d	25 e	30 e		20 e	25 e		20 e	20 e	20 e	12 e	90 e	37 e			12 e	17 e		
Boy G	—	—	—	—	—	—	65 d	—	60 d	50 e?	—	? e	(2) 30 e	(1) 90 e					22 x	25 e					15 e	20 e	10 e	10 e	14 e	13 e						
Boy H							75 de	—	120? d	—	—	—																	105 de?	105 x			28 e	—		
Boy J							—	—	—	—	—	—	60 e	67 e	10 e	15 e			10 e	10 e					10 e	12 e			7 e	5 e			5 e	8 e		
Boy K	—	—	—	—	—	45 a	—	—	45 c	30 c?	—	—	55 c?	15 c?	65 d	10 bc?			35 e?	10 e		20? x	—		45 e?	25 e?	12 a	6 e								
Girl A	—	—	—	—	—	—																			30 e	25 e	20 e	10 e	12 e	20 e			8 e	10 e	9 e	25 e
Girl B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	67 e	—	—	20 e	—	—	105 e?	27 e?	10 e	7 e	45 e	35 e			170 e	12 e		
Girl C	—	—	—				90 e	—	—	—	—	—	—	—	65 x	—	—		—	—	50 x	30 x	15 e		50 e	60 e										
Girl D	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	50 x	60 e	—		35 e	40 e	20 e	40 e	15 e	20 e	10 e	17 e	12 e	11 e		
Girl E							—	—	—	—	—	—	—	—	130 a	45 de?	127 d		—	85 d?		105 x	—		15 e	29 e	20 e	25 e	15 e	12 e	20 e	10 e	18 e	8 e	—	7 e
Girl F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—												

TABLE 7

Time Required for Each Infant to Pull the Lure in Reach, Contact, or Secure It

Situation: Single String with Grill

The time is expressed in number of seconds. Interrogation marks (?) indicate that the time was not reported. In cases where it seemed possible to estimate the time from the behavior reported, the estimated number of seconds is given, followed by a mark of interrogation. A dash (—) indicates that the lure was not pulled in reach. A blank space indicates that the situation was not given. Small-type numbers above the number of seconds indicate the order of presentations when it differed from the standard *R-L-M* order. The letters *a*, *b*, *c*, *d*, or *e* below the time numbers indicate the type of perceptive attitude (cf. pp. 260-261). The letter *x* indicates that incompleteness of the record did not permit a judgment of the perceptive attitude, and *z* indicates that the infant's interest in securing the lure seemed too slight to permit a judgment.

Boy B

32 weeks. Successes *L1* and *M1* were of Type *d*. Failure in *R2* was due to motor distraction and to difficulty in securing the string. B scratched at the string, looking back at the lure, but fell over to the right. He pulled himself to his feet, and, when replaced in position, pulled himself over to the Examiner. In *L2*, after looking from lure to string and scratching at the string, he began to fuss. *M2* is characterized by behavior that sounds like Type *e*, but the record is incomplete on the subject of regard, and therefore has not been counted in the frequencies for Figure 13. B "reaches for the string with his right hand through Space *5A*, secures string with right hand. By drawing his hand far back at right, pulls cat within reach. As soon as it is within reach, he reaches for it . . . , grasps it . . . , and carries it to his mouth."

36 weeks. R1. Type c. 50 seconds. B looks at the cat, looks down at platform, looks back at cat, turns to the right, looks at cat and bounces back and forth, waving arms and smiling. He looks at cat, brings hands together and makes a breathy noise. Pulls himself up to grill, looks down at string on right, picks it up in left hand, brings right hand to it, pulls it in a little. Cat begins to move; B looks back at cat, waves right arm and jerks string. This brings the cat about half way across the table. As soon as the cat is within reach, B seizes it.

L1. Type d. 50 seconds? B pulls himself closer to the grill, looking fixedly at the cat. He presently looks down at the string on the left, scratches at it with left hand while looking at cat. After pulling the string a little way in, he drops it, looks back at cat and is very active, waving arms, but does not try to reach it through grill. As he is too close to the grill, the Examiner moves him back a little bit. He looks at the Examiner for a few seconds, presently

looks back at the cat, picks up the string with left hand, gives it another pull which brings the cat to the edge of the table where he grasps it as soon as it is within reach.

R2. Type d. 55 seconds. B leans forward, reaches with left hand toward cat in center. He looks at the string and scratches at it a little bit with left hand. He brings right hand on table and scratches it, picks at the end of the string with his right hand. He picks up the string in his right hand, pulls cat about half way across table, waves hands and drops string. He brings both hands up to Spaces 5 and 6, picks up string again and brings cat to side of table within reach. He picks it up.

L2. Type e. 30 seconds. B leans forward; reaches through Space *5A* with left hand for the cat; then sits up straight. He reaches for string with left hand, pulls the cat about half way across the table, drops string, tries to reach cat, barely touches the tail, picks up the string with left hand, gives another jerk, drops string. Picks up cat.

Boy C

Boy C's record at 36 weeks has already been quoted. His difficulty in *R1* apparently was failure to see the string. Transitional stages between the 28-weeks period and the 36-weeks period are seen at 32 weeks, where there occurs a drop in time similar to that shown by Boy B at the same age.

32 Weeks. In *R1* and *L1* the string was not regarded. *M1* is quoted as an example of transition from Type *a* to *c* and even to *d*.

M1. Types a, c, d. 105 seconds. C regards cat for about a second, looks back at the Examiner, looks again at the cat. Looks at string, scratching at it with left hand, having reached through Space *5A*. Picks up string, carries it to mouth. As he does so, the cat tips over. Looks at cat, looks at string, pulls his left hand back and looks at cat as it comes in about half way across the table. C carries string to mouth again, holds part of string in right hand, another part in the left and looks at stretch between. Vocalizes and draws cat a little farther in. Drops string as he tries to reach cat directly. The

cat is slightly out of reach. C contacts string, scratches string, pulls string farther, looking at cat. Tries to reach cat with the right hand, touches it but does not seize it. Picks up string with left hand, pulls cat to the edge of the table and secures it.

R2 was of Types *c* and *d*. In *L2*, he fussed and slumped down in the chair, though he scratched a little at the string.

M2. Type c? 35 seconds? C looks at the cat, down at the string, scratches near it with left hand. Contacts string, begins to fuss. The cat is squeaked again. C stops fussing, picks string up with left hand, transfers it to right hand, pulls cat in reach with one pull, prehends it as soon as it is within reach. [The estimate of 35 seconds includes allowance for the fussing.]

From 36 weeks on, Boy C's performances are of Type *c*, though at 40 weeks he is a little slow to see the string on the left. At 48 weeks his expectation that the string will continue to be on the right is so strong as to result in failure. A section from the protocol is quoted here, so that the reader may see the evidence that "representative factors" were present and also the compensatory scratching of the blotter mentioned above in the case of Boy G (p. 266).

"C looks at cat, then at the right-hand side of table, and points with his index finger. Looks at Examiner and back to cat, reaching through Space 6*A* with left hand, looking at the cat and also at the table in that direction. With his right hand he reaches through Space 7*A* and seems surprised not to find the string where it was before. Drags hand in, vocalizing, 'uh uh.' Picks up the blotter on the right. Looks around the room. Turns to the left, scratching the blotter."

Boy D

Boy D was an infant much advanced in gross motor ability, with a strong motor drive and a rather im-

patient disposition. At 36 weeks, in *R1* and *L1*, there was an evident conflict of interests, in which the lure and string competed unsuccessfully with the activity of standing and bouncing up and down. After 145 seconds and 180 seconds, respectively, hope of victory for the lure and string was abandoned by the Examiner. In *M1*, though the conflict continued, there was enough positive activity toward the lure to encourage a prolongation of the period, and after 245 seconds the lure was secured, with an apparent perceptive attitude of Type *c*. After the lever situation, *R2* and *L2* were responded to with fussing, rising to a standing position, and very little evidence of interest in the lure. The infant was taken out of the examining room, since it seemed useless to proceed further. After a two-minute interval, a second opportunity with *R2* and *L2* was given. The Examiner's report is quoted below:

R2. *Type c*, *120 seconds*. D is brought back into the examining room and set on the platform before the grill. He begins to cry. The roly-poly doll is put in place with the string on the *right*. D quiets as he looks at it. He begins to fuss again but quiets as the doll is tapped on the table. He reaches for it with his right hand but turns over to the right side rail and starts to pull himself up. He sits down again with his back to the doll. The Examiner rocks the doll again. D looks at it, lowers himself to a sitting position, reaches with his left hand directly for the doll through Space 4*A* and scratches at the string with his right hand through Space 6*A*. He brings his left hand over to the string, secures the string and brings the doll half way across the table. He tries to reach it and releases the string while reaching. He fusses as he unsuccessfully reaches for the doll. While reaching for the doll, first with his left then with his right hand, he encounters the string and closes his right hand on it after several seconds. He pulls the string and brings the doll to the edge of the table.

L2. *Type e*, *45 seconds*. The doll is rocked and D looks at

it. He looks at the Examiner, fusses a little bit. He looks at the string, scratches at it with his left hand. He secures it in his left hand and draws his left hand back so that the doll comes in. By waving his hand several times he succeeds in pulling the doll to the left front corner of the table. He reaches through Space *1B* with his left hand and takes the doll by the head.

Enlistment of interest, induced in *R2* by a change of lure and enhanced in *L2* by the preceding success, seems to have been a strong facilitating factor.

Drops in Boy D's time scores after 40 weeks were due to increasing facility in the mechanics of string-pulling, or in the length of reach across the table in cases where the first tug was a short one. His adjustment to the test situation became increasingly better as standing and cruising lost some of their novelty, and this also helped to lower his time record.

Boy E

In the case of Boy E at 36 weeks, it was hard to tell whether he considered the string-pulling or the table-scratching to be the efficacious gesture. In *R1*, without the grill, he scratched the table with left and right hands while he looked at the lure and apparently did not notice the string. In *L1*, as he looked at the lure, his scratching hand was on the string. He gave a start as the lure fell over; his hand closed over the string, and he pulled the lure to the platform. In *M1* he leaned forward stretching as far as he could toward the lure and scratched the table with his left hand while he grasped the string with his right. In 15 seconds he had pulled the lure off the table. In a later presentation with grill which is quoted below from the proto-

cols, there appears to be more awareness of the string. The quotation is given in order that the behavior may be compared with that at 40 weeks where the drop in time score occurs.

36 weeks. M2. Type c. 123 seconds. E looks at the duck. Scratches on string repeatedly with his left hand. The duck begins to roll in. Scratches table top near string, his left hand almost resting on string. Secures string in hand and draws duck half way across board, 45 seconds. Looking back at it with string in hand, he scratches again on table top. Looks at string. Looks at duck. String is caught in fingers, but as he raises his hand, he lets it drop. Looks back at duck with a whistling pucker of the mouth. After 1 minute 45 seconds he looks at string again. Secures it by the thumb and side of index finger of left hand. Pulls string and in 2 minutes 3 seconds secures duck in right hand and brings mouth to wheel although duck is on the opposite side of the grill.

At 40 weeks the behavior is of Type *e* and, as the quotation below shows, would be characterized by a low time score in both presentations if it were not for the initial timidity. It was found impossible to continue this examination into the Multiple-Strings Situations because of the infant's crying.

40 weeks. R1. Type e. 60 seconds. He looks at the fish. Fish is rattled by the Examiner. For several seconds he glances at the Examiner, then back at the fish. Looks at the string on the right. Right hand tentatively approaches as it did in the cube situation, but is withdrawn. Again he looks at the Examiner. Again he approaches the string and withdraws hand, but after 40 seconds has secured string, and with a rather slow movement has pulled the fish about a third of the way across the table toward him. Releases the string as he tries to secure fish directly with left hand. He contacts it, but cannot quite reach it. Takes string about 5 inches from fish and draws fish within reach and secures it one minute after beginning of the situation.

L1. Type e. 20 seconds. After 2 minutes 40 seconds the screen is set up. E fusses a little at sight of the screen. Examiner

lays the screen down on the table. After the screen is replaced, again E shows a tendency to fuss. Screen is left in a slightly leaning position. E fusses a little as fish is taken away and put in place behind the screen. Screen is removed. E is looking at the Examiner, and fusses a little. Fish is rattled. E looks at it and fusses a little. Then he looks at the string on the left. Left hand goes slightly forward. Left hand is over string several times. He secures the string and draws fish to where he contacts it after 20 seconds. He manages to get left hand over bowl so as to draw fish to the grill after 30 seconds.

The relapse to a long time score at 44 weeks in *L1* is accounted for by the following quotation.

44 weeks. L1. Type e. 180 seconds. E is sitting somewhat back of position and slightly to the left. It seems inadvisable to move him. He leans forward and gets in front of the grill on his knees in a fairly good central position. Scratches with right hand in direction of fish. Withdraws his hand. Sits back and looks around the room. Fish is rattled again by the Examiner. E regards the Examiner. Vocalizes, "ah da umm da da." Begins pulling himself up by right side rail. Looks up at the light. Glances back at the fish. Stands over by the right side rail, then sits down. Looks back at the fish. He is about a foot and a half away from the grill. Pulls himself to his feet. Looks up at the light again. Looks over at the window. Back from it to the light. Vocalizes, "da da ada," repeatedly. Fish is rattled and he looks at it, but looks back at the light. Comes creeping from right side of crib to left side. Gets his right hand on the string. Secures it between thumb and index finger, then between thumb and middle finger. It is now 2 minutes 40 seconds since the beginning of the situation, when he picks up the string. One slow pull draws fish off table onto platform. Picks it up from platform 3 minutes after the beginning of the situation.

Boy F

Boy F at 36 weeks presents the most striking case of a rather sudden appearance of Type *e* within a given examination period. In *R1*, *L1*, and *M1*, he at no time contacted the string, though he apparently looked

at it from time to time and once moved his hand toward it a little. He regarded the lure frequently, but his behavior was of the type referred to in a previous section as "less adaptive." When the grill was removed, and the same lure was used again, the behavior was as quoted below:

36 weeks. Without grill. R1. Type d. 40 seconds. F looks at cat and smiles a little bit. As he pats the table top, his right hand comes down on string. He secures it in his hand and pats on the table top. Transfers it to his left hand. Looks back at the cat as it falls over. Looks at string. Another tug brings cat to where he has secured it about 40 seconds after beginning of the situation.

L1. Type e. 16 seconds. [Note resemblance of initial behavior to that in the preceding situation.] F looks at cat, pats table top with right hand over at the right. Looks over at right where he is patting. Looks over to left. After patting table top once in that direction, he picks up the string, watching the cat come in. With one tug he brings cat to where he secures it 16 seconds after the beginning of the situation. Transfers it from one hand to the other. Drops it on the table. Scratches at the string. Picks up the string and draws cat a little way on the table. Carries it to his mouth, having secured it again.

When the grill was replaced the string evidently was not seen at first, an example of the functioning of the grill as a visual barrier. The nature of the success in *M2* led the Examiner to present *R2* and *L2* again.

36 weeks. R2. 90 seconds. F's gaze goes to the fish from the screen. Fish is rattled by the Examiner. F continues looking at it for about 10 seconds. Looks at the Examiner momentarily. Looks back with a prolonged regard for the fish. Looks from fish down to near edge of table. Looks over to right side rail and grasps it with right hand. Strains toward left side rail with left hand. Examiner shakes the fish again. F looks at it. Turns again to pulling toward side rail. He is moved away from the rail by the Examiner, but his hand goes back to side rail. Looks toward Examiner, extending right hand toward her.

L2. 55 seconds. F looks at fish for about 3 or 4 seconds. Glances to the left of the room. Again at the fish. Leans to the right and picks up blotter. Gaze comes back to the fish. Looks up to the ceiling, and down to the fish, protesting momentarily. Looks around the room. Gaze comes back to the fish and rests there for about 3 seconds. He sputters, looking at the Examiner.

M2. Type d. 25 seconds. F regards fish. Gaze comes down to the string. As soon as he sees the string, he picks it up in his left hand. Watches the fish come in to about 4 inches from edge of the table. Looks at it. Picks up string again. Gaze goes to the fish, which is in easy reach. He secures it 25 seconds after beginning of situation. Waves it up and down, carries it to his mouth, and hits it on the grill. Transfers it from one hand to the other. Vocalizes as he chews on it.

R2 repeated. Type d. 20 seconds. F looks at the fish. After about 8 seconds he looks at the string on the right, fingers it with his right hand. He begins to pull string. With two tugs he has pulled fish to where he secures it 20 seconds after beginning of situation. Puts it back on the table. Picks it up again. Releases it again. Drops it on the platform. Picks it up by the string. Hits it on the grill.

L2 repeated. Type e. 18 seconds. He looks from fish to string. Picks string up in left hand after 10 seconds. Looks at fish as he begins pulling string. One tug brings fish almost to edge of table. Another tug brings it through the grill. He has secured it about 18 seconds after beginning of situation. Drops it, picks it up by string, and drags it around on the platform by the string. Picks it up from the platform and drops it, then bounces it around again. He pulls it across his lap by the string from the right to the left side of the platform.

Here in the situation with grill the drop in time appears, if not surely with Type *e*, at least with an attitude toward the string very different from that in *R*1 and *L*1.

The lengthened time at 48 weeks marks Boy F's first and only maladjustment to the examination.

Boy J

Boy J at 36 weeks has two rather long time scores with Type *e* behavior and delayed regard for the string, followed by brief times.

36 weeks. R1. Type e. 60 seconds. J smiles a little as he leans forward looking at the cat. Extends his left hand far out on the table, scratching the table top in the direction of the cat with his right hand. Pulls himself to grill so that his chair swings around and he looks startled. Chair is moved into position again by the Examiner. J looks at the Examiner. Reaches to left side rail, looking at it. Gaze comes back to the cat. After 50 seconds, he has looked at the string. Secures it in his right hand, looking at the cat as he does so. He pulls string. One tug brings cat to where he contacts it 60 seconds after the beginning of the situation.

L1. Type e. 67 seconds. J is looking at the cat before it is squeaked. Continues looking at it. Leans forward. Pulls himself to the grill, tipping the chair forward, open mouth approaching Bar 4. Chair is brought down to the platform by the Examiner. Looks to right side of table. Turns to left, pulling at Examiner. Pulls himself up to grill, again tipping himself forward in chair. Chair is brought down by the Examiner. He begins kicking with both knees under the table top, rocking back and forth, watching the cat. Hits grill with both hands. Pulls himself close to grill, opening mouth as he approaches Bar 4. After 55 seconds he secures the string in left hand. Pulls it in watching the cat. Brings cat with one tug to edge of table and secures it as soon as it is in reach.

The first of the Multiple-Strings Situations is quoted next, since it follows in the examination.

Perpendicular Parallel Strings. R1. 25 seconds. Looks from doll down to the string. Reaches for string with left hand, then with right hand, looking at the doll as he scratches and opens and closes his fingers on string, evidently trying to prehend it. After 20 seconds he has secured the string and brought the doll with one tug to where he contacts it about 25 seconds after the beginning of the situation.

At 32 weeks Boy J's only successes were in the

situation without grill, and they were of Types *b* and *c* although the time was short.

Boy K

Boy K is a case that is hard to classify but his record is presented rather fully so as to make plain the difficulties that it offers. At 32 weeks in *M*1 and *R*2 he brought the lure in reach in a time that is remarkably short at that age, and, though his behavior is classified as Type *c*, one must admit that it sounds very much like that which has been called Type *e* in other cases. One factor which led to giving the lower classification to these successes was their inconsistency with the behavior in the performances that followed. Yet this lowering of quality may have been due to the thwarting influence of mechanical difficulties.

32 weeks. M1. Type c. 45 seconds. Squeaking of the cat calls his gaze to it. He looks at it for several seconds. Glances down. Looks at it again, and then glances down. Looks over to the left, glances down. Looks over to the right. After 20 seconds, while he is looking down at the string, left hand begins scratching on it. Draws it a little bit through the grill. Draws cat half way across table. Looks at the cat there, having released string. Gets right hand through Space 5*A* onto cat. Has secured it about 45 seconds after the beginning of the situation.

R 2. Type c. 30 seconds. K regards cat for several seconds. Glances over to the left. Looks down at his dress. Looks back at the cat with rather a prolonged regard. After 15 seconds he has glanced over at the string on the right. Immediately begins scratching at it with right hand. As he scratches at it, he watches the cat as it begins to come in. One tug brings cat to where he contacts it 30 seconds after the beginning of the situation. It is then at the edge of table. He fingers it. Draws back his right hand over the string to the full length of the string. Does this about four times. The cat is caught around Bar 7 and does not come through the

grill. Carries string to his mouth. Rubs right foot on the platform. Draws string back again with right hand as before. String is caught over the fingers of his right hand. Continues holding it there as he draws hand back from grill. Fingers cat as it lies on the edge of the table.

L2. 165 seconds. K regards cat, but glances over to the left. Looks at the cat, at the ceiling, then at the Examiner. Looks back at the cat. Fingers his right bootie. Regards the cat. After 30 seconds he has looked at the string on the left. Looks back to cat as he pokes at string. Draws back left hand at side. Cat comes one-fourth of the way in and falls over. Looks at it, scratching down on the platform by the end of the string there. Does not secure the string. Looks at the cat, with both hands on the grill. Looks at the Examiner with a prolonged regard. Then looks back at the cat momentarily, but looks at the Examiner and smiles. Rubs left foot on the platform and picks at his bootie. After 1 minute 45 seconds he is extending left hand through Space 3*B* toward the cat, but withdraws it. Looks over to the left. Examiner squeaks cat again. Looks at it, but looks up at Examiner's hand which is over the top of the side rail. Looks down at string which is over edge of the platform. Fingers it. Looks up at the Examiner and smiles. Looks around the room.

M2. 90 seconds. K was already looking at the fish. Extends left hand in direction of it through Space 3*B*. Then right goes through Space 6*B*. Scratches a little on the table top. Glances at string. Scratches at string, while looking at the fish. Left hand, scratching on string through Space 3*B*, is not able to prehend string. Right hand goes through Space 5*B* toward the fish. Brings right hand down on the string. Scratches at the string a little. Extends right arm to right side rail. Looks around at the Examiner. Back at the fish. His face is close to the grill. Both hands are on the grill. He is moved a little farther away from the grill by the Examiner. Fish is rattled again. Looks at the fish, then over at the Examiner. Looks back at the fish, and perhaps down at the string, but does not approach the string. After 1 minute 30 seconds the fish is brought by Examiner to the edge of the table where K secures it.

At 36 weeks, greater facility with the left hand seems to cause the fluctuations in time records, which

are long when the string is on the right and very brief when it is on the left. In both cases where the string is on the right, the left hand finally has to come to the aid of the right.

36 weeks. R1. Type c? 55 seconds. K looks at the fish. Slides up very close to the grill. Puts his right hand through Space 6, left through *4B*, toward the fish, though the right hand also seems to approach the string. After 15 seconds he has moved the string almost to the median line with his right hand through Space *6B*, while looking at the fish. Then he brings his hand in through Space *6A*. He scratches at the string, while regarding the fish all the time. Brings the fish with one tug half way across the table. Then he puts his right arm through *7B* and scratches on the string which he has released. Withdraws his hand. He approaches it with his left hand through Space *4B*, then with right hand through *7B*. He secures the string and brings the fish to where he contacts it 55 seconds after the beginning of the situation, but he cannot well secure it there with his right hand. He secures the string in his left hand. He draws the fish to the edge of the table in the median position, where he draws it with string through the grill 1 minute 25 seconds after the beginning of the situation. He secures it 1 minute 35 seconds after the beginning of the situation with his left hand, the string being looped around the base of Bar 4.

L1. Type e? 15 seconds. K leans forward with his face close to the grill. He extends his left hand through Space *4A* and gets it on the string as he looks at the fish. He contacts the fish 15 seconds after the beginning of the situation, and by holding the string close to the fish, has brought it to the edge of the table and pulled it through the grill 25 seconds after the beginning of the situation. Then he secures it in his right hand. Carries to his mouth.

R2. Type d. 65 seconds. K looks at cat intently all the time it is squeaked. He sits up straighter and leans forward a little. Right hand goes through Space *6B* while he is looking at the cat, also looking at the string which his hand is approaching. Looks from string to cat. His left hand moves in a little bit on the grill. He secures the string in his right hand between thumb and index finger 40 seconds after the beginning of the situation, but simply waves his hand up and down. Does not pull string in. Re-

leases it. Secures in left hand. Pulls cat half way in. Drops string. Seems to be reaching directly for the cat. Contacts it 1 minute 5 seconds after the beginning of the situation with his right hand, through Space *6B*. Draws fingers back along the string. Looks down at the string. Secures string with left hand. Draws left hand back and contacts cat. Secures cat by the tail 1 minute 25 seconds after the beginning of the situation.

L2. Type b? c. 10 seconds. Looks at the fish. Gets left hand on string without having seemed to be particularly looking at the string. Looks off to the left corner of the crib. By pulling the string he brings the fish to where he contacts it 10 seconds after the beginning of the situation. Drops string and makes an attempt to secure fish directly, but does not secure it until 40 seconds after the beginning of the situation.

A drop to a consistently lower level does not occur until 40 weeks, and here the check on the consistency is almost lost because of the crying at the end of the examination. The preference for the left hand appears again here.

40 weeks. R1. Type e? 85 seconds. K leans forward giving the cat a prolonged regard. After 15 seconds his left hand goes up to the junction of Bars 3 and *A*, then his right hand goes up to Bars 4 and *A*. He leans over close to the grill, looking at the cat. He looks at the Examiner, at the lower frame of the grill, at the cat, and up at the Examiner. He scratches on the table through Space *6A*. He has not yet regarded the string apparently. After one minute he glances over to the right. He may have seen the string then, but he looks farther around toward the back of the crib. His gaze comes back to the string. He contacts it with his right hand and pulls end of it off table. Secures the string in left hand. After 1 minute 25 seconds he has contacted the cat, having brought it with one tug to the edge of the table.

L1. Type e. 10 seconds. K looks at the fish, then immediately down at the string on the left. Looks back at the fish. Gets his left hand on the string. Secures the string. While looking at the fish, pulls the fish with one tug of his left hand to the edge of the table and contacts it 10 seconds after the beginning of the situation.

[The high grade assigned to *R*1 seems partly to have been inferred from the behavior in *L*1.]

R2. Type x. (Record incomplete on subject of regard.) 20 seconds? Bell is removed. The screen is removed. K begins to cry and continues crying while extending his left hand toward the automobile. After 15 seconds he secures the string and pulls automobile off the table. He picks it up, but continues crying as he holds it in his mouth. The bell is set on the platform and he stops crying.

In *L*2, the Examiner did not venture to remove the bell from K, and he made no approach to the lure or the string.

At 44 weeks, *R*1 required 45 seconds because Boy K cried for 40 seconds before he looked at the string. In *L*1 his time would have been shorter if he had not had difficulty in prehension of the string. These two performances are classed as Type *e?* since the interest seemed to be as much in the act of pulling as in securing the lure. *R*2 and *L*2 were of Type *e*.

Girl C

Girl C's success at 40 weeks in *M*1 and *R*2 are classed as Type *x*, since the record with reference to the securing of the string was felt to be too incomplete. The two presentations of *L*2 quoted below illustrate one type of distraction that occasionally arose, and the improvement in the behavior when the distraction was past.

40 weeks. L2. C gives a prolonged regard to the cat. Glances over to the right to her mother momentarily. Looks down at her right knee as she kicks with right foot on the platform. Grunts. Squeaking of the cat calls her regard back to it. Cat is also hit on the table. She regards it. Pulls herself close to the grill. Does not seem to regard the string yet. Moved back from the grill by her mother. Pulls herself up close to the grill, bumping head on the

grill while regarding the cat. Kicks her right foot on the platform while regarding the cat. Voids. Is taken out to be changed. Mother reports that home training in reference to elimination has begun.

L2 repeated. Type e. 15 seconds. When put back in the crib, she begins to fuss a little. Quiets as she looks at the fish. Looks from fish to string on the left. Secures string in left hand. With one slow tug brings fish to edge of table, contacts, secures, and draws it through the grill 15 seconds after the beginning of the situation.

Girl C never presents a drop to a consistently low level, since her records end with 44 weeks, and at this age, although *R*1 and *L*1 seem to be of Type *e*, the time is long because of motor distraction and delayed regard for the string. At 44 weeks Girl C displayed only a mild interest in the cat when it was exposed with the string on the right. After 80 seconds the screen was set up; the fish was substituted for the cat; and *R*1 and *L*1 followed as quoted below.

44 weeks. R1. Type e. 50 seconds. Looking at the fish, she slides close to the grill, almost sliding under it. Her feet are active on the platform, pushing her up; both hands on the grill. Her regard is for the fish. She is pulled back from the grill into position by the Examiner. The fish is rattled again. This time she looks from the fish to the string. Immediately, 35 seconds after the beginning of the situation, she secures the string in her right hand. With one tug she brings the fish off the table onto the platform and picks it up from the platform 50 seconds after the beginning of the situation.

L1. Type e. 60 seconds. C looks at the duck. Extends her right hand through the grill onto the table through Space *7A*. She pulls herself close to the grill and almost slides under the table. She is pulled back into better position by the Examiner. Her right hand makes an approach to the duck and her left hand pulls her up to the grill so that she almost falls over backward. After 40 seconds she appears to regard the string for the first time. She reaches for it with her left hand though her right hand is still extended toward

the duck through Space *6B*. After one minute she secures the duck by the head, having brought it with one tug to the edge of the table.

Girl D

Girl D's behavior at 40 weeks was much complicated by a tendency to pull herself to standing by means of the grill. Aside from *M*1, where the record is classed as *x* on account of the gaps it presents, the only occasion where this distraction was overcome was *R*2, where the success was of Type *e*.

40 weeks. R2. Type e. 60 seconds. D extends right arm as far as it will go through Space *5B* toward the fish, while regarding it. Then both hands go on the grill and she pulls herself to it, almost sliding under. She is pulled back by the Examiner. She seems to glance toward the string and her right hand moves in that direction, but it may have been moving to right side rail, toward which she is now pulling herself. Begins to cry. Fish is rattled again after 45 seconds. Extends right hand toward the string through Space *5B*. After 55 seconds looks from string to fish. Secures string, looking at fish. Pulls in fish. Pulls off table onto platform 60 seconds after the beginning of the situation. By waving string which is now in her left hand, having transferred it from the right, she draws fish toward her from the platform. Picks it up after 1 minute 15 seconds.

At 44 weeks there is a solid array of Type *e* successes; but delay of regard for the string, combined with a tendency to motor distraction, keeps the time fairly long. A greater readiness to remain seated brings the time reduction at 48 weeks.

Girl E

In the case of Girl E, the factors keeping the time high until 44 weeks appear to be motor difficulty in pulling and a tendency to find satisfaction in chewing

the string. Girl E was more addicted to sucking her thumb than any other infant in the group.

40 weeks. R1. E is looking at the cat when it is squeaked. After looking at the cat for several seconds she glances at the Examiner, again at the cat. Right hand is active on Bar *A*, at 4 and 5. After 20 seconds she begins approaching string with left hand, having looked at the string. Withdraws her left hand and approaches the string with her right hand, looking from string to cat and back to string as she attempts to prehend the string. Moves the string about on the table top until it is in the median line, while she attempts to prehend it. In reaching over, she leans too far to the left, falls over, and bumps her head on the grill. Begins to cry a little as she is picked up. Stops when the bell is given to her.

L1. Type d? 85 seconds. E looks from the cat to the string, then back to the cat. Looks back and forth. She approaches the string with her left hand, draws the string through the grill without producing movement of the cat, then picks up the string as she pulls it in, causing cat to fall over. Looks back at the cat, then at the string. Resecures string, which she has dropped meanwhile. She pulls string to her mouth but does not put it in. Looks at the cat, which is 6 inches from the edge of the table. Drops the string and leans forward. Picks up string in left hand and carries it to her mouth, watching the cat as she does so. Has secured the cat 1 minute 25 seconds after the beginning of the situation.

R2. (Resembles Type a, but not classified because motivation seemed too slight.) 105 seconds. E looks from the cat to the Examiner; then looks back to the string. Begins moving her hand over the string, looking back at the cat as she does so. Looking back and forth from cat to string, after 20 seconds she secures string in her left hand, causing the cat to fall over. Looks at it. Carries string to her mouth and chews it. Looks at the Examiner. Looks back at the cat. Draws the string out of her mouth as she rocks back a little. The cat moves in a little. E looks around, chewing the string. Cat is now about half way across the table. After 1 minute 30 seconds she picks up the string in her left hand, and as she is turning to the side to look at the Examiner this movement draws cat to edge of table top where she contacts it 1 minute 45 seconds after the beginning of the situation.

Change of lure for *L2* produced no better results.

By 44 weeks, both the motor difficulty and the string-chewing have disappeared.

44 weeks. R1. Type e. 15 seconds. E looks at the cat, at the Examiner, and back at the cat, then over to the string on the right. Secures string in right hand while looking at the cat. Draws right hand back at side. One smooth, rather slow tug brings cat to edge of the table where it is contacted 15 seconds after the beginning of the situation. Secures and draws through grill.

Boys A and H

Lest the time records for Boy A and Boy H raise some question, a note of explanation is given here. The brief time for Boy A at 44 weeks is not to be considered evidence of remarkable adaptation on a first encounter with the test situation, since he was present at all four of the preceding ages, but his protocols were discarded because the method of the experiment had not yet reached its final form.

Boy H was not examined at 36, 40, and 44 weeks. His long time record at 48 weeks is not to be considered as due to lack of examination experience, however, since he was perhaps the most irritable and sensitive of all the subjects until the 52-weeks examination. At 28 weeks his was the case that was discarded because of persistent crying. A quotation from his 48-weeks protocol accounts for the 105 seconds.

48 weeks. R1. Type e. 105 seconds. H looks at the cat, waves his right hand at his mother, rocks back and forth, holding on to the grill with his left hand, looks at his mother, and looks at the cat. After 30 seconds, he looks over at the string on the right, and his right hand approaches it, but he withdraws it again. He looks at his mother, and looks around the room with his right hand on the grill. The cat is squeaked again after a few seconds. After 1 minute and 25 seconds, H glances at the string, approaches it with his

right and left hands, secures it in his left hand, and pulls it in a little so that the cat falls over. He looks back at the cat as it falls over, leans over and secures the string again in his left hand, having dropped it, and brings the cat with one tug to the edge of the table where he contacts and secures it.

In the Perpendicular-Parallel-Strings Situation immediately following these long periods, success required only 30 and 15 seconds in the two presentations.

* * * * *

The relations between time score and perceptive attitude detailed above may be summarized as follows:

1. An abrupt drop in time score to a consistently lower level may occur when a success of Type *e* follows successes of a lower type or actual failures. Examples:

   Boy B—36 weeks
   Boy C—32-36 weeks
   Boy D—36 weeks (Type *e* accompanies interest enlisted through preceding success)
   Boy F—36 weeks (the first reduced score here comes with Type *d*)

2. The time score may be long, even with behavior of Type *e*, because of delayed regard for the string. In such cases the significant drop may follow one or two presentations in which Type *e* appears. Examples:

   Boy G—36 weeks
   Boy J—36 weeks
   Boy K—40 weeks
   Girl B—44 weeks

3. The time score may be long even with behavior of Type *e* because of initial timidity. The time then

falls when the emotional adjustment becomes better. Examples:

Boy E—40 weeks

Boy H—48 weeks

4. The time score may be long even with behavior of Type *e* when motor distractions are combined with delayed regard for the string. Examples:

Girl C—44 weeks

Girl D—40 and 44 weeks (drop at 48 weeks)

5. The significant drop in time score may occur between examinations as Type *e* develops along with a decrease in distractibility and an increase in motor capacity. Example:

Girl E—40-44 weeks

6. Pronounced irregularities in time score in a given examination may occur where facility with one hand is greater than facility with the other. Example:

Boy K—36 weeks

VI

ANALYSIS OF THE MATERIAL: MULTIPLE-STRINGS SITUATIONS

The Selection of the String for Initial Pulling

In the Multiple-Strings Situations the first problem to be given consideration is the selection of the string for the initial pull. Figure 15 shows for each situation at each age the percentage of presentations in which (*a*) the attached string was pulled first; (*b*) the median string was pulled first; (*c*) the remotest string was pulled first; (*d*) no string was pulled.

The selection of the string to be pulled first in the several Multiple-Strings Situations seems to depend (a) on the visual pattern presented at the moment, with the lure considered as the dominating feature; (b) on the pre-existing tendencies to reach in a given direction or with a given hand; and (c) on the presence or absence of more general disturbing factors. All of these influences may vary with age.

In the Perpendicular-Parallel-Strings Situation there was a pronounced preference for the attached string, and the remotest string was least likely to be pulled. The preference for the attached string reached its maximum at 48 weeks. The slight drop at 52 weeks will be commented on later. One may wonder why, in spite of its visual disadvantage, the remotest string retained to 52 weeks even the slight influence that it did. This may be due to the persisting from the preceding Single-String Situation of a tendency to reach to the right or left of the lure to

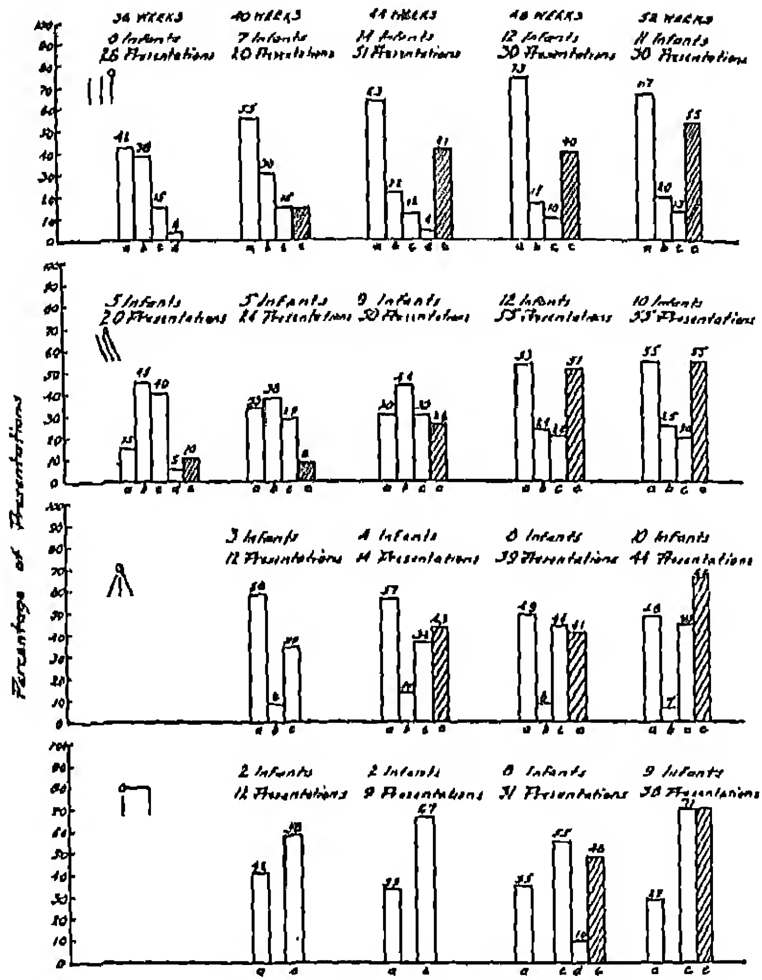

FIGURE 15

SELECTION OF THE STRING FOR INITIAL PULLING IN THE SEVERAL MULTIPLE-STRINGS SITUATIONS

a—attached string; *b*—remotest string; *c*—median string; *d*—no string pulled; *ex*—locomotor activity.

Note: Occasional discrepancies in percentages are due to simultaneous pulling of two loose strings.

secure the string. The median string, which had a similar rightness or leftness with respect to the lure, and which had the additional advantage of closer proximity to the lure, always exerted a greater attraction than the remotest string.

In the Oblique-Parallel-Strings Situation the odds were in favor of the median string until 48 weeks. From this time on, the attached string received a majority of the first choices. By 48 weeks there may have been more of a tendency than there was earlier to respond to the general right or left sweep of the pattern, and more initial tendency to reach over to right or left for a string rather than directly toward the lure. As additional evidence in support of the latter interpretation, we may note that in the Single-String Situation 48 weeks showed the conspicuous drop in direct approach to the lure (Figure 5).

In the Converging-Strings Situation, after 40 and 44 weeks, where the small number of cases may account for the unexpectedly large proportion of successes, the odds were practically even between the right-hand and the left-hand string with respect to the initial pulling. Though the median string appears to have been almost negligible in the initial pulling, it played a part in the succeeding behavior, and, if the attached and median strings were left to choose from after the first pull, the median string was fully as likely as the attached string to be the second choice. In this situation, where the visual advantage of the attached string is slight, the choice seems to be strongly influenced by pre-existing tendencies to reach in a given direction. At 48 weeks,

out of 8 infants, 3 made all their correct initial choices on the right, 2 on the left, and only one was correct in as many as three-fourths of the choices. At 52 weeks, out of 10 infants, 3 made all their correct initial choices on the right, 3 on the left, and one was correct in three-fourths of his initial choices. Such "position habits" are discussed in a later section.

Even if the choice in this situation were determined purely by visual factors, perhaps the results would be similar. The attached and the remotest strings form an isosceles triangle with the near edge of the table as a base. As one looks at such a triangle, the two lines that meet at the apex and form the sides of the figure impress one more than a line bisecting the apical angle.

On the other hand, in some preliminary experiments when the Converging-Strings Situation was tried without being preceded by the other members of the test series, the Examiner got the impression that the median string was naturally preferred by the infant, and this was one reason why the lure was never attached to the median string in the final experimental series. This observation favors the "position habit" explanation of the results shown in Figure 15. Köhler found that in his multiple-strings experiment it was *either* the most direct string *or the one on the right* that was pulled first (20, p. 28).

In the Roundabout-and-Direct-Strings Situation, the preponderance of first choices went to the direct but unattached string. The graphs for this situation furnish the converse to those for the Perpendicular-Parallel-Strings. Such correct initial choices as there are seem to be largely due to the favoring influence of right or left position habits. No infant at any time was correct in all his initial choices. At 48 weeks, however, there was one infant who seemed to correct his errors, making wrong first choices on the first presentation and correct first choices on the second presentation, both on the right and on the left.

The visual pattern in general, rather than in detail, seems to have been a determining influence. That infants at this age are incapable of exact discriminating response to such visual patterns as the Converging-Strings and the Roundabout-and-Direct-Strings is not proved by these experiments. To determine this point, it would be necessary to deny rather than briefly delay success if the initial choice were wrong, and to see how many trials were necessary to establish consistent correctness. This would be extremely difficult, though perhaps not impossible. Any form of punishment other than delay would be likely to make the infant negative to the entire situation. Even under the conditions of our experiment, one infant developed such negativity.

Table 8 shows how small was the median time advantage that was gained by pulling the attached string first rather than a loose string.

TABLE 8

TIME REQUIRED TO PULL THE LURE IN REACH IN THE MULTIPLE-STRINGS SITUATIONS

Median time (seconds) required to pull the lure in reach (*a*) when attached string was pulled first and no loose strings were separately pulled, (*b*) when one or more loose strings were pulled before the lure was brought completely in reach.

Situation		44 weeks	48 weeks	52 weeks
Perpendicular-Parallel-Strings	(*a*)	18	15	10
	(*b*)	37	20	17
Oblique-Parallel-Strings	(*a*)		10	10
	(*b*)		20	20
Converging-Strings	(*a*)			10
	(*b*)			18
Roundabout-and-Direct-Strings	(*a*)			8
	(*b*)			13

The transition from 48 to 52 weeks is marked in general by a slight decrease rather than an increase in the proportion of correct initial choices. A phenomenon correlated with this, and perhaps explanatory, is the increase in the percentage of presentations that were preceded, accompanied, or followed by standing or locomotor activity. The locomotor drive seems to have been a disturbing element even when it did not actually take the child away from his activity with the lure and strings. At 52 weeks, where the number of infants remains approximately the same throughout the series of situations, one notices that the amount of motor activity becomes greater as the examination progresses.

Aside from the drop between 48 and 52 weeks, the effect of increasing age on the proportion of correct initial choices seems to be generally favorable in the Perpendicular-Parallel and Oblique-Strings Situations, but not in the Converging and Roundabout-and-Direct. In the latter two situations, however, the number of infants at 40 and 44 weeks is too small to justify the first conclusion that the graph suggests, namely, that increase in age has an unfavorable effect. In the case of some individual infants the decline which appears for the group at 52 weeks is noticeable earlier.

Certain supplementary data not taken into account in Figure 15 are given in Table 9.

In Item 1, it seems logical that the situation in which some loose string most frequently was pulled in along with the correct string should be the Oblique-Parallel-Strings Situation. Where such pulling of two strings at once occurred in other situations it was usually because both right and left hands went on the table at once. This

approach with both hands occurred in several instances at 52 weeks, though it rarely resulted in the exactly simultaneous pulling of two strings.

If the attached string were insecurely grasped, the resistance offered by the lure might cause it to snap out of the infant's fingers. Before it was resecured and drawn in, some loose string might be pulled. Item 2 shows that such pulling of a loose string before resecuring the attached string was most likely to occur in the Oblique-Parallel-Strings Situation. The proximity of the strings and their general arrangement in this situation make this result seem reasonable.

From Item 3 it is evident that at 44 weeks there would be an appreciable drop in the column for correct initial choice in the Perpendicular-Parallel-Strings Situation if a deduction were made for the cases where the attached string, though selected for initial prehension, was never pulled sufficiently to bring the lure in reach.

Item 4 presents evidence of correction of errors, especially in the Converging-Strings Situation at 48 weeks and in the Roundabout-and-Direct-Strings Situation at 52 weeks. Such abandonment of a loose string after pulling it in only a little distance could not occur if the pull were very impulsive and vigorous. It might be due to feeling the lack of the anticipated resistance from the lure, or to the fact that the lure was not seen to move in according to expectation.

When a loose string was the first to be pulled, the direction of the infant's gaze suggested that he was pulling this string as a means to secure the lure. In the Perpendicular-Parallel-Strings Situation, where this item is reported most consistently in the protocols, regard for the lure at the time of reaching for or pulling the loose string is reported in all the cases of erroneous initial pulling at 36 and 40 weeks and in 94% of the cases at 44 weeks. The behavior of Boy E at 44 weeks is quoted here in illustration of this point, and also of the correction of errors mentioned above.

Perpendicular Parallel Strings. R1. Looking at the doll, E puts left hand on median string. Begins pulling it slowly in; watches doll all this time. When it is pulled half way in, he releases the string. Picks up right-hand string with left hand. Slowly and cautiously, watching the doll, he begins to pull it in. As the doll moves, he gives a decided start. Gets his hand on the doll 30 seconds after the beginning of the situation.

Occasionally the infant who had pulled in a loose string "looked

TABLE 9

DATA SUPPLEMENTARY TO FIGURE 15

	36 Weeks		40 Weeks				44 Weeks				48 Weeks				52 Weeks			
	PP	OP	PP	OP	C	RD	PP	OP	C	RD	PP	OP	C	RD	PP	OP	C	RD
1. Percentage of presentations in which a loose string was pulled along with the attached string in the initial pulling	—	—	—	8	—	—	—	—	—	—	3	7	—	—	3	4	2	3
2. Percentage of presentations in which the attached string, selected for first prehension, snapped out of the fingers	—	5	—	—	—	—	4	2	—	—	—	4	13	—	10	9	—	—
and a loose string was then pulled before the attached string was resecured	—	—	—	—	—	—	2	2	—	—	—	4	3	—	—	9	—	—
3. Percentage of presentations in which the attached string, though selected for initial prehension, was never pulled sufficiently to bring the lure in reach	—	—	—	—	—	—	12	—	—	—	—	—	—	—	—	2	—	—
4. Percentage of presentations in which a loose string was left lying on the table after being pulled in half way or less, and the attached string was pulled later	—	—	—	—	—	—	6	2	—	11	3	7	21	3	3	5	9	13

puzzled" or seemed to refer the loose string back to the lure. Boy C at 40 weeks in the Oblique-Parallel-Strings Situation "looks at the duck; looks at the strings; looks back at the duck and pulls the string farthest to the left (remotest string). He looks at the string and waves it a little. Looks back at the duck and reaches through the grill, holding out the string toward the duck. He looks at the string as he holds it out at the right over the platform. He looks back at the duck, picks up the right-hand string (attached) in his right hand and draws the duck with one tug to the edge of the table." This sort of behavior occurred more often at 36 and 40 weeks than at the later ages. The older infants would proceed rather promptly to pull another string, discarding the first one.

Rather often, on the other hand, at 36 and 40 and even at 44 weeks, the infant who initially pulled a loose string proceeded to activity which seemed to be more concerned with the loose string than with the lure. Sometimes there was a possibility that this activity was a sort of reference to the lure. Waving of the hand that holds a string, for example, seems to be one of the infant's methods of pulling. Unless this activity appeared very definitely to be directed toward the lure, it was counted as mere "activity concerned with the string." This behavior was rare after 44 weeks. Its earlier frequency may be an indication of a greater distractibility from the original goal or of greater interest in the string itself. The frequency of such behavior is shown in Table 10, Item 1. Item 2 in this table is given merely as a basis of reference for Item 1. Such activity concerned with a loose string did not always prevent later pulling of the correct string, nor are all failures to secure the lure traceable to such distraction.

Item 3 in Table 10, to be considered in relation to Item 4, may be further evidence for a certain amount of interest in the string itself, or indication of a perseverative tendency, or a sign of the persisting of some initial unsatisfied impulse. This pulling in of a loose string after the lure has been brought in reach occurs most commonly in the Perpendicular-Parallel-Strings Situation. In this situation the loose string more likely to be pulled is the median. If the remotest string is pulled in, the median string precedes it. The order of preference here is the same as the order of preference in the initial pulling. Why does this phenomenon appear so much oftener in this situation than in the Converging-Strings Situation? In the former situation the median string may have exerted an initial attraction

TABLE 10

EVIDENCE OF INTEREST IN THE LOOSE STRINGS

	36 Weeks		40 Weeks				44 Weeks				48 Weeks				52 Weeks			
	PP	*OP*	*PP*	*OP*	*C*	*RD*	*PP*	*OP*	*C*	*RD*	*PP*	*OP*	*C*	*RD*	*PP*	*OP*	*C*	*RD*
1. Percentage of presentations in which there was temporary activity showing interest in a loose string that had been pulled in rather than in the lure	27	15	15	29	—	33	4	14	21	22	—	4	5	3	3	5	5	—
2. Percentage of presentations in which a loose string was first to be pulled	53	80	45	67	42	58	34	70	45	67	27	47	51	55	33	45	52	71
3. Percentage of presentations in which a loose string was pulled in after the lure had been pulled in reach	—	—	10	4	8	—	16	4	7	—	22	7	5	—	30	13	5	—
4. Percentage of presentations in which one or more loose strings remained on the table after the lure was pulled in	62	35	70	54	75	42	71	54	72	33	87	73	67	33	87	82	68	26

which was overcome by the attraction of the attached string, but which produced an effect later. In the latter situation, Figure 15 shows that the initial impulse, if not directed toward the attached string, was directed toward the remotest string. If it were directed toward the remotest string, the latter was likely to be pulled in first, so that no unsatisfied impulse remained. There never was a strong initial impulse toward the median string in the Converging-Strings Situation, since by this stage in an examination there was often established a habit of reaching to the right or the left but not down the center of the table toward the lure. This habit existed to a less degree in the Perpendicular-Parallel-Strings Situation, and, furthermore, in this situation the median string actually occupied a right or left position with reference to the lure.

The Relative Difficulty of the Several Situations

Figure 16 shows the relative difficulty of the four Multiple-Strings Situations better than any of the other figures. The relative difficulty appears to depend, as one would expect, on the directness with which the loose strings lead toward the lure.

The Instability of the Level of Selective Response

In compiling the data from the Perpendicular-Parallel-Strings Situation for Figure 16, it was found desirable to consider separately the presentations before the lever situation. In the majority of cases at 48 and 52 weeks the series of string situations was gone through only once (see Figure 3). Where it was repeated, the performance in the Perpendicular-Parallel-Strings Situation in several cases showed one error, though it had been perfect before. This happened in the case of two infants at 44 weeks, three at

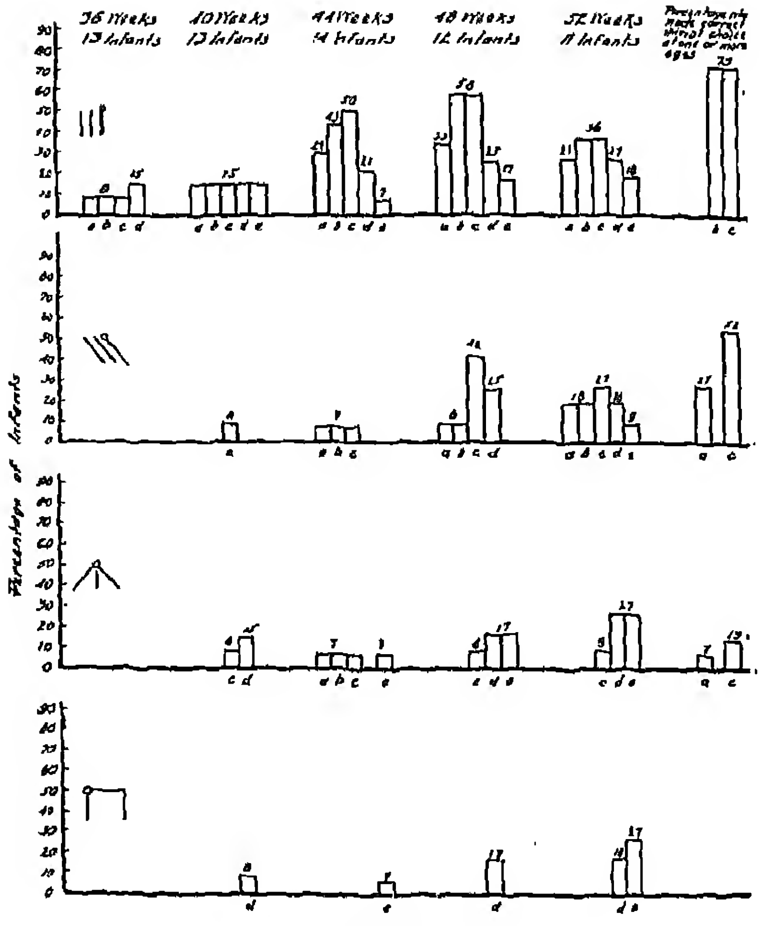

FIGURE 16

PERCENTAGE OF INFANTS WHO MADE A GIVEN PROPORTION OF CORRECT INITIAL CHOICES IN THE SEVERAL MULTIPLE-STRINGS SITUATIONS

Percentage of the total number of infants examined at the several ages who made correct initial choices in (*a*) all presentations; (*b*) all presentations before the lever situation; (*c*) three-fourths or more of all presentations; (*d*) all presentations on the right but not on the left; (*e*) all presentations on the left but not on the right.

48 weeks, and one at 52 weeks. Fatigue or loss of interest might have been responsible, or an increasing tendency to "position habit." In the other Multiple-Strings Situations this factor seemed to make no difference, perhaps because there was less to lose.

Further evidence of the instability of the level of the selective response in the Multiple-Strings Situations can be found in Figure 16 by comparing the set of columns at the right-hand edge of the page with the preceding groups of columns in the same line. This last set of columns probably needs more explanation than the legend provides. The percentages in this set of columns have been obtained by dividing the total number of infants who at any age made correct initial choices in all or in at least three-fourths of the presentations of a given situation by the total number (15) who entered upon the Multiple-Strings Situations. This total percentage for the first two situations is larger than the corresponding percentage at any one of the preceding ages.

Examination of the actual composition of the group represented by Column *c* at successive ages will make this point clearer. In the Perpendicular-Parallel-Strings Situation the infants who make up Column *c* at 44 weeks are Boys B, C, D, G, J, and Girls A and E. At 48 weeks they are Boys A, C, F, H, J, and Girls D and E. Infants who were in the experimental group at both times but who were more successful at 44 weeks are Boys B, D, and G, and Girl A. At 52 weeks Boys B and D reappear. Boy G was not examined at this age; otherwise those examined were the same group as

at 48 weeks. Boys A, C, F, H, and Girl E displayed a lower degree of selectivity in their response at 52 weeks than at 48 weeks. Boy J is the sole infant who is represented in Column *c* at all three ages. It is interesting to note that in the Oblique-Parallel-Strings Situation, also, he is the only one that consistently contributes to Column *c* at 44, 48, and 52 weeks. Except for him the infants in this situation represented by Column *c* at 52 weeks are entirely different from those at 48 weeks, though all the infants in question were examined at both ages. In the Converging-Strings Situation, Column *c* at 44 weeks represents simply Boy J, though at 48 weeks it represents Boy G. Yet the record of even this most consistent of our subjects reveals some fluctuations. If we examine the composition of Column *a*, we find Boy J always present from 44 weeks on in the Perpendicular-Parallel-Strings Situation. In both the Oblique-Parallel and the Converging-Strings Situations, however, his only perfect record is at 44 weeks. His protocols, quoted in the Appendix, make it clear that emotional adjustment to the examination was the variable factor in his case.

Position Habits

Every one of the 13 infants who had more than one session with the Multiple-Strings Situation displayed a "position habit" in one or more situations at one or more ages. Table 11 shows for each infant the situation, the age, and the direction in which the one-sided successes appeared.

The data are summarized below.

INFANT	36 Weeks	40 Weeks			44 Weeks			48 Weeks				52 Weeks			
Boy A					R							R			
Boy B								L	R[2]						
Boy C			R			L	L			L			L	L	L
Boy D		R						R	R						
Boy F		R	R		R					R		L		L	L
Boy G	R							R	R						
Boy H												R	R	R	
Boy J	R	L[1]		R											
Boy K		L													
Girl A								R			R	R		R	R
Girl B					L			L				L			
Girl D					R					R	R		R	R	R
Girl E										L				L	L

1. Accidental; not counted as a position habit.
2. A left position habit that interfered with success on the left.

TABLE 11

Distribution of Position Habits by Infants, Situations, and Ages

R signifies that when the attached string was on the right the initial choice was always correct, but when the attached string was on the left the initial choice was always wrong. *L* signifies the converse of *R*.

Total number of situations marked by position habit		47
	Right	29
	Left	18
Total number of infants displaying position habit		13
	Right	9
	Left	6
Number of infants maintaining the same direction of position habit at two or more ages		11
Number who exhibited shifts of position habit between ages (these infants also maintained the same direction for two or more ages)		2

The relation of position habits to handedness is perhaps the first question that suggests itself. Unfortunately, the protocols do not always state which hand was used. In the case of all but one infant, however, there is enough of a record in at least one situation at one age to make possible the following summarization:

Right position habit with rather strong right handedness (Right hand even reaches over finally to pull left-hand string)	3 infants
Right position habit with occasional or exclusive use of the left hand in reaching over to pull the right-hand string	3 infants
Left position habit with use of left hand	5 infants
(*a*) Left hand pulls left-hand string first, but right hand pulls right-hand string	4 infants
(*b*) Left hand occasionally reaches over finally to pull right-hand string	1 infant
Left position habit with occasional or exclusive use of the right hand in reaching over to the left	1 infant

Position habits are certainly not exclusively a matter of handedness.

Another question that may be raised is as follows:

In a given position habit, is it always the same hand that approaches the given direction, and does it always approach the same spot?

The protocols permit the following tentative summary, based on the 47 situations:

1.	Record inadequate	21
2.	Hand and general direction of initial reaching remain the same	19
3.	General direction of reaching remains the same but hand changes	3
4.	Hand remains the same, but general direction of initial reaching varies	3
5.	Both hand and direction of reaching change	1

The numbers here tally too well with the total; the matter is not so simple as they make it appear. "General direction of reaching" is not an exact term and has probably been much too generously applied. Probably Item 2 should be smaller and Item 4 larger. Perhaps the case in Item 5 can hardly be called a position habit.

The three cases of change of the reaching hand with maintenance of the general direction of reaching deserve special attention, since they indicate that position habits may sometimes represent a rather general orientation in a given direction. The protocols for these cases are quoted in the Appendix. One of them is Boy J at 40 weeks in the Roundabout-and-Direct-Strings Situation. Even the general orientation is only partly the same here from one presentation to another. A clearer case is that of Girl D at 52 weeks in the Converging-Strings Situation. In this situation the arrangement of strings and lure is more favorable to the

maintenance of a constant general orientation. Girl D was one of the three "rather strongly right-handed" infants at 48 weeks. The case of Boy H at 52 weeks is characterized by a shift in the preferred hand from right to left with continuance of a right direction tendency.

The relative frequency of position habits in the several situations must be considered in relation to the number of infants who were given the situations. When a calculation is made on this basis, position habits are found to have been most frequent in the Converging-Strings Situation and least frequent in the Oblique-Parallel-Strings Situation.

Summary of Observations of Position Habits

1. Right position habits were more common than left. The ratio was about three to two.
2. The direction of the position habit for a given child tended to remain constant from one period to another.
3. Position habits were only occasionally accompanied by clear evidence of corresponding handedness.
4. A position habit usually was characterized by movement of a constant hand in an approximately constant general direction.
5. Occasionally a position habit seemed to be merely a general orientation in a given direction and the reaching was sometimes with one hand, sometimes with the other.
6. Position habits occurred most frequently in the Converging-Strings Situation and least frequently in the Oblique-Parallel-Strings Situation.

VII

COMPARISON OF RESULTS AND CONCLUSIONS WITH THOSE OF OTHER INVESTIGATORS

Comparison with Animal Investigations

Our findings agree with those of Adams (1, p. 161) to the effect that motor and perceptual adaptation develop together. The alliance of the adaptation with maturation was brought out in the case of the infant. At 44 weeks, and in some cases earlier, the attitude of our infants toward the string and lure resembled that of Köhler's chimpanzees (20, p. 27), but we found earlier examples of less insightful behavior. At these earlier levels there were some examples of rather prompt learning by attention to a sequence of events (cf. Hobhouse, 18, p. 241), of which perhaps the most striking is that of Boy F at 36 weeks (p. 286). If we should try to fit our results into Hobhouse's categories (18, pp. 241, 270), we might say that a perceptive attitude of Type *c* indicates at least "practical ideas" and even a certain degree of "articulation." Probably the line between practical and articulate ideas is no easier to draw than that between partial insight and complete insight. Our results in the Multiple-Strings Experiments indicates that there was not complete analysis of what was perceived (cf. Hobhouse), but the behavior here was complicated by the haste and impulsiveness of the infants. With regard to Tolman's analysis (35, pp. 46-51), we might infer that there was "representation" and "fore-

sight" in the case of Boy F to which we have just referred, when a rather slight "chance-produced" movement of the lure was followed by a tug that appeared purposeful and that brought the lure in reach. "Representation of the ends of acts" could not forestall overt errors when the behavior was strongly impulsive, but at times it was in evidence. There appears to be an example of such mental correction in the behavior of Boy J at 40 weeks in the Perpendicular-Parallel-Strings Situation (Appendix, p. 341) when he aproaches the median string but passes on to the correct left-hand string without securing the unattached one. In our Single-String Situations, when the infant was sufficiently mature, it often seemed as if simply on sight of the string he passed from a postulation that the lure was inaccessible to the postulation that it was attainable and to appropriate action. If he saw the string immediately, there was no initial postulation of unattainability. At this stage one would probably not say that he was *learning through insight* (or foresight): rather, he was *acting with appropriate insight* or in accordance with an adequate perception of the whole situation.

Comparison with Studies of Infants

In a comparison of our study with other studies of infants, the emphasis is on results in relation to age level rather than on theoretical interpretation. Such a comparison must take account of differences in method. Our infants were selected from a social-economic-educational group distinctly superior to that of either the Yale Clinic or the Vienna Institute sub-

jects (cf. p. 218 above). The presence of the grill has been demonstrated to make the situation more difficult. The differences between our method of presentation and the Yale normative methods can be seen by referring to pages 201 and 217. The comparative results of these two studies are given in Table 12, our results here being in terms of number of infants rather

TABLE 12

COMPARISON OF RESULTS WITH THOSE OF THE YALE NORMATIVE STUDIES

	Percentage of infants who pull lure in reach at the several ages				
	28 weeks	32 weeks	36 weeks	40 weeks	44 weeks
Preliminary report, Yale normative group	25	47	83	95	94
Group used in this study, with grill	0	54	69	92	100

It is rather interesting that 44 weeks, the age at which our *group* uniformly achieved success in every presentation, whether on right or left (see Figure 5), corresponds to the "end of the tenth month" at which time K. Bühler (6) reports for his one subject that the string was always looked for and pulled, no matter in what position it lay.

than number of presentations, and taking account only of the presentations with the string on the right or the left. The differences in method seem to cancel each other out to a considerable degree after 28 weeks. In C. Bühler's series (5) the procedure calls for placing the string in or near the child's hand, and the test is placed at 11 months.

The absorption in the string which Peiser (26) observed in an infant at the age of a year resembles the

Type *a* behavior which we found chiefly in the situation without grill at 28 weeks, though it seems probable that the exploitation of the string by the year-old infant was of a higher grade.

VIII

THE PROBLEM OF MOTIVATION

Nature of the Motivation

Though the question of motivation is only incidental to the main purpose of this study, nevertheless it is a fundamental problem of method. In animal experimentation of this sort, the lure is usually food, though it may be some special delicacy rather than the daily ration. Our experiment relied on the fact that if an object suitable for grasping is placed before an infant six months to a year old it is fairly sure to be grasped and manipulated, mouthed, or otherwise exploited. The behavior does not suggest a "possessive instinct," a desire merely to secure the object for the sake of owning it. Rather, the object seems to provide a focus for the general "activity drive."[3] Thus the lure in our experiment had to compete with other objects that were at hand or with mere gross motor activity such as rocking back and forth, creeping, standing, or cruising. In animal experimentation the question whether the string rather than the lure might be the objective is sometimes raised, and in infant experimentation it is even more pertinent.

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[3]The activity drive is beginning to receive more consideration in animal experimentation. Washburn's (36) distinction between "activity-driven" and "hunger-driven" mice, Tolman's (35) comments on the fact that in mazes sometimes the short blinds are eliminated first and sometimes the long blinds, and Nissen's (25) study of exploratory behavior in the white rat are examples.

Adequacy of the Motivation

That the motivation used in this experiment was fairly adequate to the problem is indicated by the fact that the results have a rather definite form. The vitality of the motivation was sufficient so that at 52 weeks 7 out of 11 infants pulled a lure in reach in 15 to 20 presentations and 3 infants in more than 20 presentations, in the course of about 50 minutes. At 48 and 52 weeks there were eight occasions on which the infant himself replaced the lure far out on the table and used the string to draw it in once more.

Competing Interests

Figure 17 serves as something of an index to the amount of competition offered to the lure by the string, by other objects, and by gross motor activity in the Single-String-with-Grill Situation.

At 28 weeks the string was something of an object of interest in itself, and, when secured, was likely to be held and inspected or carried to the mouth. After 32 weeks this initial interest in the string was negligible. The question of interest in the string in the Multiple-Strings Situation was discussed on page 309.

Distraction of activity to other objects than the lure and the string does not include activity of the hands on grill and table top or in contact with other objects unless there seemed to be genuine distraction of interest from the lure. As the capacity to secure the lure increased, this distraction disappeared.

Gross motor activity was somewhat more of a distracting factor than the graph indicates, since in some

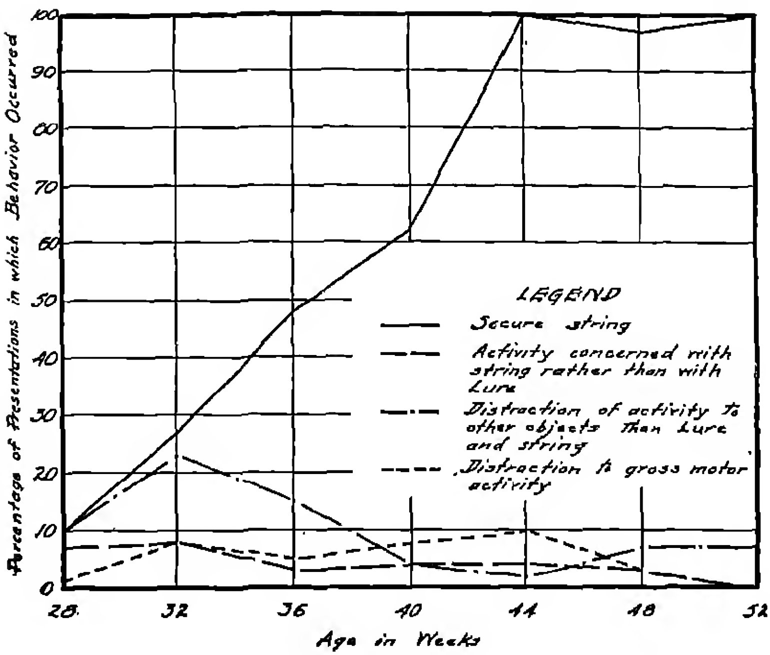

FIGURE 17
MOTIVES CONFLICTING WITH THE DRIVE TO PULL IN THE LURE
Situation: Single String with Grill

presentations where the lure offered too slight an inducement a change of lure brought better results and the re-presentation has been substituted in the tabulations. Inclusion of such cases would never raise the curve by more than 6%, and this maximum change would occur at ages 36, 40, and 44 weeks. Gross motor activity was reckoned as a distraction only if it definitely seemed to take the infant away from the lure. Even when it was not an actual distraction, it sometimes was a distinct disturbing factor. At 48 and 52 weeks the infants did not pull themselves up and cruise away

before pulling in the lure, but they had just been standing and cruising and they were probably "set" to return to this activity. The possible influence of this factor in the Multiple-Strings Situations was discussed on page 305.

Limitations of the Motivation

In addition to the existence of these competing interests there seem to be other limitations to the use of our form of motivation. In the Multiple-Strings Situations the motivation was almost always sufficient to insure pulling the lure in reach, and the lure seems to have been an important factor in determining the selection of a string for initial pulling. Yet the technique was not one that tested the ability to make perfect discriminatory responses. Further experimentation would be needed to ascertain the usability of this form of motivation with such a technique.

There are limitations to the length of time that an infant can be kept at pulling strings, even with variations in the lure. At 52 weeks the interest of Girl A suddenly gave out at the beginning of the twenty-fifth presentation. "She looks at the doll, but pulls herself up by the left side rail and reaches for the Examiner's mouth. Also points at the thermometer."

Factors Influencing the Value of the Lure

The plan of the experiment called for the employment of a specific lure with each situation. This plan was adhered to in the main, but not rigidly; for it was realized that the objective identity of the lure was no guarantee of its subjective equivalence when used with

two different infants or when used twice with the same infant. Though a systematic study of the factors influencing the value of the lure would be a problem in itself, some suggestions may be found in our data.

Objective Factors. There was some evidence that the fish was more attractive than the other lures, even when it had no greater advantage from novelty. The bright clear color and the noise-making capacity might have been the superior features.

Subjective Factors. 1. Relative novelty was a factor of advantage. Too great familiarity with the lure either at home or in the examination reduced the interest. The fish had been a favorite lure for Girl D through all the examinations until the age of 48 weeks. At this age she seemed to be distinctly less attracted to it than to other lures. Her mother reported that at that time she had a similar fish among her toys at home. At 52 weeks the fish was approached as eagerly and mouthed as long as other lures. The fish at home was reported to have been lost during the interval. At 44 weeks Boy G rocked back and forth and cried at the fourth exposure of the roly-poly doll (the second successive exposure in the latter half of the examination). When the ball was substituted for the doll, he promptly secured the string and brought the ball rolling off the table, picked it up, and poked at it. It may be that the negative attitude toward the doll was partly induced by its recent removal; for he had fussed during the interval between presentations.

2. Great difficulty experienced in the activity seems sometimes to have produced an aversion to the lure.

This is partly a matter of temperament. Three of the infants at 32 weeks, in a total of five presentations, pulled the lure part way in or even within reach, and then began to cry, leaving it untouched. These were the three infants who ranked as "rather consistently irritable" from 28 to 40 weeks. Two of them had the same rank between 44 and 52 weeks.

3. Success seemed to be responsible for increased interest in the activity in the case of Boy D described on page 284.

IX

SUMMARY OF RESULTS AND CONCLUSIONS

SINGLE-STRING SITUATIONS

1. Between 28 and 44 weeks the infants displayed (*a*) a rapid development in adaptive response to the situation; (*b*) a dropping-out of the less adaptive forms of behavior. At 28 weeks, in the situation with the grill, the lure was pulled in reach in 3% of the presentations, at 44 weeks in 100%.

2. Relatively abrupt drops for the group in the median time required to bring the lure in reach appeared at 40 and 44 weeks.

3. At 28 and 32 weeks the grill was one of the main factors that prevented the securing of the string and the pulling in reach of the lure. Successes when the grill was removed were frequent. The interference that the grill offered was chiefly mechanical but partly visual. From 44 weeks on, the influence of the grill was negligible.

4. Between 28 and 44 weeks there was rapid development in the motor capacity to prehend and to pull the string. The main behavior items that have been considered an index to this development are (*a*) difficulty in securing the string, (*b*) the number of tugs given before the lure was brought in reach. Both of these items were influenced by perceptive and emotional attitude toward the whole situation as well as by motor capacity.

5. The facts stated above demonstrate that the adaptive utilization of a string requires the maturation of certain motor capacities.

6. Five types of perceptive attitude, representing different levels of maturity, were inferred from the total behavior during the securing of the string and pulling in of the lure:

a. Interest in the string rather than in the lure.

b. Interest in the lure and apparently accidental contact with the string.

c. Awareness of both lure and string without evident purposive utilization of the string.

d. Experimentation.

e. Definite utilization of the string as a means to bring the lure in reach.

Types *a* and *b* may be said to represent success without insight; Types *c* and *d*, success with incomplete insight; Type *e*, success with insight.

7. Types *a* and *b* made most of their appearances in the situation without the grill. With the grill there were relatively few successes that were not of Type *e*.

8. From Item 7 we may conclude that perceptive capacity and motor capacity to overcome the difficulties offered by the grill develop together. With the open table top, motor capacity may be in advance of perceptive response. With the grill in place, perception may at times seem to be in advance of motor ability.

9. In the course of the infant's development insight into this simple problem, in the sense of awareness of the means to an end, appears in varying degrees, and is lacking in stability and flexibility at first.

10. When sufficient maturity is reached, there are instances where a new and adequate envisagement of the situation seems to make its appearance with relative suddenness and to be followed by performances of a consistently higher level. Sometimes this change seems to come from the perception of a sequence of events then and there, sometimes from catching sight of the string. In the latter case there may have been earlier perceptions of sequences of events in similar but not identical situations.

11. The presence of a sudden drop in time score usually is a symptom of a perceptive attitude of Type *e*. It may either mark the first appearance of Type *e* or it may come following a performance in which behavior of Type *e* was retarded by delayed regard for the string, by initial timidity, or by motor distraction. The general reduction in median time score between 28 and 52 weeks is probably due both to motor development and to perceptive development.

Multiple-Strings Situations

1. The selection of the string to be pulled first in the several situations seems to depend (*a*) on the visual pattern presented at the moment, with the lure considered as the dominating element; (*b*) on the preexisting tendencies to reach in a given direction or with a given hand; and (*c*) on the presence or absence of more general disturbing factors.

2. The relative difficulty of the several situations seems to be determined by the directness with which the loose strings lead toward the lure.

3. The level of the selective response to the lure and multiple strings is unstable. Variations in locomotor drive, in interest in the lure, and in emotional adjustment to the examination seem to be factors that prevent a consistent improvement in selective response with advance in age. Some infants tend in general to maintain a higher level than others.

4. Position habits appeared in a number of cases. They were only occasionally accompanied by strong evidence of corresponding handedness. Sometimes they involved a change of the reaching hand with a maintenance of the preferred direction of reaching.

X

PROBLEMS SUGGESTED FOR FURTHER STUDY

1. The development of prehension of the string requires cinema analysis for adequate study.

2. Development in the mechanics of traction is another problem that would profit by photographic study.

3. It would be desirable to know the extent of visual span of the infant from age to age and to consider this in relation to perceptive attitude and to the capacity for regarding the lure while reaching for the string.

4. Another experiment might investigate the possibility of obtaining a higher degree of discriminatory responses in the Multiple-Strings Situations.

5. It was uncertain from our results whether the unattached oblique string in the Converging-Strings Situation had a visual advantage over the median string, or whether its advantage was due solely to the motor tendency to reach to right or left of the lure.

6. A more complete study of the relation of position habits to handedness and of the variability of a position habit is needed.

7. The relative value of food and toys as instigators of problem-solving activity might be investigated.

8. The influence of subjective factors such as familiarity, success, and failure on the value of the lure could be studied as a separate problem.

9. Beginning at 44 weeks, more difficult single-

string problems might be introduced, such as the tied string or the diagonal string tests.

Digest

In this investigation the development of adaptive behavior in infants was studied by means of problems calling for the utilization of a string to secure an otherwise inaccessible "lure." The subjects were 16 infants from superior homes who were observed at intervals of 4 weeks from the ages of 28 to 52 weeks, in a total of 88 examinations. The situations were displayed on a table top, usually behind a grill. Single-String Situations were first given with the grill in place and were re-presented without the grill in cases of failure. Multiple-Strings Situations, offering loose strings along with the attached string, were presented with the grill in place, after success with the first set of Single-String Situations. The Multiple-Strings Situaations were of four types, forming a graded series: three perpendicular parallel strings; three oblique parallel strings; three converging strings; and a roundabout and a direct string.

In the Single-String Situations at 28 and 32 weeks the grill was both a mechanical and a visual hindrance to success. At 44 weeks its influence was negligible. Between 28 and 44 weeks the percentage of successes in the Single-String Situation with grill rose from 3 to 100. This period was marked by development both of motor capacity and of perceptive attitude. "Insight" into the utility of the string appeared to be present in increasing degree with increasing age. The time re-

quired for pulling the lure in reach was found to be related to perceptive attitude as well as to motor capacity.

In the Multiple-Strings Situations the selection of the string for initial pulling appeared to depend (*a*) on the visual pattern presented by the lure and strings with the lure as the dominating element; (*b*) on tendencies to reach in a given direction or with a given hand; and (*c*) on the presence or absence of more general disturbing factors.

APPENDIX

Excerpts from Protocols: Multiple-Strings Situations

Girl D

52 weeks

Oblique Parallel Strings

R1(a)

D looks at the duck, reaches over for the right-hand string with her right hand, scratches on it several times, approaches it then with her left hand, drops the string at the edge of the table, finally secures it 17 seconds after the beginning of the situation in her left hand, brings the duck with one tug to the edge of the table, and secures it 24 seconds after the beginning of the situation.

R1(b)

D remains sitting in position this time. She turns around to the left, is turned back by the Examiner, and the screen is removed. She looks at the ball, with her right hand reaches over for the right-hand string, secures it, brings the ball rolling over the table with one tug, and picks it up from the platform 5 seconds after the beginning of the situation.

L1(a)

D's hands are approaching the right at the time the screen is removed, but the Examiner sets her so that her hands are in position. She looks at the duck as it is tapped on the table. Her right hand goes on the table, scratches on the right-hand string and draws on it, bringing it down on the platform and continuing to hold it. Looking over at the left-hand string, she secures it in her left hand and brings the duck with one tug to about 5 inches from the edge of the table, and secures it 25 seconds after the beginning of the situation. She carries it through the grill, momentarily to her mouth, releases it on the platform, pulls in the median string with her left hand, drops it on the platform, pulls herself up by the left side rail, and vocalizes "Ah" to her mother.

L1(b)

D pushes at the screen during the interval, stands up in front of the grill, and lowers herself near the duck on the platform. The

duck is removed. D is moved into position and is in position when her mother removes the screen. She looks at the ball, extends her right hand on the table pulling in the right-hand string, and shakes it off on the platform at her right. Her left hand approaches the left-hand string, secures it, and brings the ball rolling with one tug to the edge of the table where she secures it 15 seconds after the beginning of the situation.

Converging strings

R1(a)

D is set down from her position on her knees by the side rail, moved into position, and her mother removes the screen. She looks at the doll, reaches over for the right-hand string with her right hand, secures it, and with one slow tug brings the doll to the edge of the table where she contacts it 7 seconds after the beginning of the situation. She secures it 1 second later, draws it through the grill, and immediately to her mouth.

L1(a)

D looks at the doll, reaches over for the right-hand string with her *left* hand, scratches on it while glancing at the doll and also at the string, pulls the string in, drops it on the platform, looks back at the doll, pulls in the median string with her left hand, discards it on the platform, picks up the string but drops it immediately, looks at the doll, from the doll to the left-hand string, and secures the left-hand string. It drops out of her fingers, but she re-secures it, drops it again, scratches on it with her left hand, then approaches it with her right hand, secures it finally, and brings the doll to the edge of the table, and 50 seconds after the beginning of the situation she secures it there.

Boy H

52 weeks

Perpendicular Parallel Strings

R1

H looks at the doll, looks down at the end of the right hand string, secures the string in his right hand, and looks at the doll as he slowly pulls it with three tugs to the very edge of the table, contacting it there 25 seconds after the beginning of the situation. The pulling of the doll was done first by a tug with the right hand, and

then while the right hand still held the string, the left hand took hold farther along, and gave two additional tugs.

L1

H's right hand goes on the table in the neighborhood of the right hand string, then swerves in and pulls in the median string. He is looking at the duck, and with his left hand reaches away over to the right, and pulls in the right-hand string. Both the median and the right-hand strings are dropped on the platform. Then with his left hand he secures the left-hand string, and 25 seconds after the beginning of the situation, he has secured the duck having brought it with one tug to the edge of the table.

Oblique Parallel Strings

R1 (a)

He looks from the ball to the end of the right-hand string, secures it in his left hand, brings the ball rolling off the table with one tug onto the platform, picks it up and carries it to his mouth. 10 seconds.

R1(b)

H reaches over to the right-hand string, secures it with his left hand, and then with his left hand pulls on the string bringing the duck off the table to the platform, securing it 15 seconds after the beginning of the situation.

L1(a)

Looking at the doll, H gets his left hand on the table, and contacts the right-hand string. Then he pulls in the median string, transfers this to his right hand, and while he is holding it down on the platform, he reaches for the left-hand string with his left hand. After several unsuccessful trials, he secures it, and brings the doll to the platform 25 seconds after the beginning of the situation.

L1(b)

Both hands go on the table—the left hand trying to secure the string. Left hand draws back about 3 times on the median string, secures the right-hand string, and pulls it in. Left hand hastily goes back and pulls in the median string, and both these strings are dropped quickly on the platform. Left hand goes back and re-secures the left-hand string, and the duck is pulled off the table to the platform with two tugs, 25 seconds after the beginning of the situation. H picks it up in his left hand.

Boy J

36 weeks

3:46 P.M. The screen is removed revealing the doll on the *right* with *Perpendicular Parallel Strings*. J is looking at the Examiner, but he looks at the doll as it is rocked. Looks from doll down to the string. Reaches for string with left hand, then with right hand, looking at the doll as he scratches and opens and closes his fingers on string, evidently trying to prehend it. After 20 seconds he has secured the string and brought the doll with one tug to where he contacts it about 25 seconds after the beginning of the situation. Has some difficulty in drawing it through the grill, and tugs at the string as he tries to get it through the grill. Finally he pulls it through and holds it suspended by the string, the string hanging around the base of Bar 7. Drops it on the platform and secures it by the head later and dangles it by a short length of the string. Transfers it from one hand to the other. Drops it under the table. Scratches at the string, attempting to secure it, and watching the doll as he scratches at the string. Secures the string and draws doll within reach and get his hand on it. It falls out of reach again. He takes the string, draws it closer, and finally secures it 2 minutes after the beginning of the situation.

3:50 P.M. Screen is set up. Doll is removed with J looking after it. He reaches quickly for the screen. Pulls himself to grill and almost tips over. Doll is put in place on the *left* with three *Perpendicular Parallel Strings*. Screen is removed. J already is looking at the doll when it is rocked. Looking at the doll, he extends first his left then his right hand through grill in Spaces 3 and 6*B* respectively. Finally he gets right hand on right-hand string. Starts to pull it, glancing back at the doll. Goes back to the string, scratching at it. Both hands are active. Left hand comes over toward the string also. Secures it and drops it on the platform at the left. Reaches to the Examiner with left hand. Kicks with both feet. Extends both hands over table top through grill. Looks at the median string. Looks at the doll as he begins scratching at it. Continues scratching at the string. Pulls it in with left hand to his side. Looks at the doll. Carries string to his mouth and sucks hand holding string, but regards the doll. Extends left hand through Space 3*B*, looking at the doll. Pulls himself to grill with both hands on it. Leans forward, watching the doll. Tips the chair forward. After 2 minutes has pulled himself toward the grill, but has not yet

contacted left-hand string. After 2 minutes 20 seconds he begins scratching on this string, however. Moves it over a little toward the median. Pulls himself up to grill. Tries to get mouth over Bar *B*. Looks down at the string. Scratches at it with left hand while looking at the doll. Picks up string. Looks at doll. Brings doll to where he contacts it 2 minutes 50 seconds after the beginning of the situation. Picks it up. Draws through grill. Secures it and carries to mouth 3 minutes 5 seconds after the beginning of the situation.

[After lever situation]

4:05 P.M. Behind the screen the doll is put in place with three *Perpendicular Parallel Strings,* correct string on the *right.* Cat is removed. Screen is removed. J is already looking at the doll. Begins scratching toward the right-hand string with both hands. Secures string in left hand. Draws doll half way across table. Extends left hand toward it. Cannot touch it. Secures string and pulls it again. Contacts doll 15 seconds after the beginning of the situation. Secures it and draws through the grill 20 seconds after the beginning of the situation. Carries to mouth. Removes it and inspects it. Vocalizes in a satisfied tone.

4:07 P.M. While mouthing the doll, he holds the string out in his left hand. Holds the doll in his mouth with his right hand. It is difficult to remove the doll, and J holds on to the string, but it is removed. Then he turns his attention to the grill and screen. Doll is put in place on the *left* with three *Perpendicular Parallel Strings.* Screen is removed. Doll is rocked. J, looking at the doll, extends right hand on table on the median string. Pulls it in. Discards it on the platform. Reaches for left-hand string. Has secured it and drawn doll with one tug to edge of table and secured it 13 seconds after the beginning of the situation. Carries through the grill and to his mouth. Chews it. Removes it. Left hand approaches right-hand string, but he does not pull it in. Attention returns to the doll which he is mouthing.

4:09 P.M. Screen is set up. Duck is put in place with three *Oblique Parallel Strings,* correct string on the *right.*. Doll is removed. J immediately extends right hand toward duck through Space *5A*. Then he draws in left-hand string with his left hand. Immediately discards it. Reaches for right-hand string. Secures it with right hand. Contacts duck 10 seconds after the beginning of

the situation, having brought it within reach with one tug. He pursues it with left hand. Knocks it almost out of reach, but manages to get his hand on it. After once neglecting the string in his attempt to re-secure the duck, later he takes the string in his right hand and draws the duck toward him. Brings it off the table to the platform about 40 seconds after the beginning of the situation. Hits it on the grill.

4:11 P.M. Screen is set up. It is rather difficult to remove the duck again. J hangs on to the string. Duck is removed. J turns his attention to the screen. Duck is put in place as before, correct string on the *right*. Screen is removed. J, looking at the duck, extends his right arm through Space *5B*. Looks down at left-hand string. Scratches at string. Drops it to the left. Pulls in median string. Discards it on the right. Reaches for string on the right. Picks it up. One tug draws duck to where he contacts it, then secures it, 20 seconds after the beginning of the situation. Draws it through the grill and carries to his mouth.

4:13 P.M. The examination is concluded.

40 weeks

3:56 P.M. Screen is set up. Doll is put in place on the *right* with three *Perpendicular Parallel Strings*. Cat is removed. Screen is removed. J is already looking at the doll when it is rocked. Right hand is extended through Space *7B*. He withdraws his hand, approaches through Space *6A*, and scratches on the right-hand string while looking at the doll. As he scratches on the string, he moves it over toward the median string, which is included in the scratching. Median string comes in and is discarded on the platform. Looks at right-hand string. Secures it and brings doll with one tug to the edge of the table where he gets it by the head 30 seconds after the beginning of the situation. Holds it out on table. Hits it on the table, arm extended through Space *5A*. After 45 seconds he carries it through the grill. Holds it in both hands, looking at it. Returns to hitting it on the grill.

3:57 P.M. Screen is set up. Doll is removed and put in place with the string on the *left*, three *Perpendicular Parallel Strings*. Screen is removed. J is looking at the doll. Extends right hand through Space *5A*. Although he moves the median string, he does not secure it. Secures left-hand string with left hand. Draws it in enough so that the cat falls over. Takes left-hand string and pulls

cat within reach and contacts it 15 seconds after the beginning of the situation. Carries through grill and drops on the platform. Picks it up. Hits it on the grill. Inspects it. Carries toward mouth, but not all the way there. Hits it on the grill and platform. Transfers it from hand to hand. Waves around at his side. Holds it out looking at it; looks at the Examiner also.

3:59 P.M. Screen is set up. Duck is put in place on the *right* with three *Oblique Parallel Strings*. Doll is removed. Screen is removed. J looks at the duck. Reaches over toward the right. Secures both right-hand and median strings in grasp, but while he is scratching on the strings his aim seems to be more for the right-hand string. After 10 seconds he has pulled the duck off the table to the platform, with one tug. Picks it up from the platform 3 seconds later. Hits it on the grill. String is caught around the base of Bar 5. Right hand is holding both the duck and the loop of the string. Takes end of string in left hand while holding duck in right. Transfers duck to left hand. Dangles it by a bit of the string that is caught around the two wheels. Picks it up again. Drops it on the platform. Re-secures it.

4:01 P.M. Duck is removed and put in place as before, three *Oblique Parallel Strings*, correct string on the *right*. J scratches at the screen. Screen is removed. Looks at the duck. His right hand is extended toward the duck through Space 5*A*. He scratches on the table top, pulling in median string. Drops on the platform. Looks back at duck. Begins scratching with right hand on right-hand string. Does not secure it in right hand. Secures it in left hand. After 20 seconds has brought the duck with one tug to the edge of the table and secured it and brought it through the grill. Hits it on the platform. Hits it on the grill. Vocalizes. Holds it through Space 6*C* over the table. Withdraws it and hits it on the platform.

4:03 P.M. Screen is set up. J is beginning to pull himself up to the grill. He is given the small bells and is moved away by the Examiner. Ball is put in place on the *left* with three *Oblique Parallel Strings*. Bells are removed. Screen is removed. He looks at the ball. Extends right arm toward it through Space 5*A*. Pulls median string about three-fourths of the way in. Leaves on table. Immediately secures left-hand string 15 seconds after the beginning of the situation, and has contacted the ball at the edge of the table, to which one tug has brought it. Secures it 5 seconds later and car-

ries it through the grill. Carries to mouth. Removes. Inspects and hits it on the platform. Brings up again, holding it in both hands. Holds ball in one hand and pats it with the other. Takes string 3 inches from the ball and holds it dangling by the string.

4:05 P.M. Ball is removed. J pulls himself up to his knees, peering over the screen, but sits down again. Ball is put in place as before, correct string on *left*. J is in position as the screen is removed. Looks at the ball. Extends left hand toward the ball through Space 4*A*. Moves the right-hand string over, but does not seem to attempt to secure it. After 15 seconds he contacts the ball, having secured the string in left hand and brought the ball with one tug to the edge of the table. He is holding it with both hands on the table 5 seconds later. Continues holding it there for some time, looking at the Examiner. String is caught around the base of Bar 3. After 20 seconds the ball falls to the platform. J shows a strong tendency to look at the Examiner just now. He is moved back from the grill.

4:07 P.M. Screen is set up. Doll is put in place with *Converging Strings*, correct string on the *right*. J is moved back into position. The screen is removed. He looks at the doll. With his right hand he scratches on the right-hand string. Withdraws right hand. Left hand approaches the right-hand string. Right hand again, then left hand. Right hand scratches beyond the string. He tends to look at the doll more than at the string, but glances at the string. One tug brings doll to eight inches from the edge of the table. Extends hand toward it but does not reach it. Another tug brings doll to the edge of the table where he takes it by the head through the grill to mouth. He coughs. Removes doll. Inspects it, turning it around. Vocalizes in a sort of little satisfied grunt.

4:09 P.M. Doll is removed and put in place on the *left* with three *Converging Strings*. J is in position when the screen is removed. He looks at the doll. Right hand reaches for the right-hand string. He pulls it in. Continues looking at the doll. Extends left hand through space 3*B* toward the doll and string. Withdraws hand. Through Space 2*B* scratches on the string, still with left hand. Withdraws hand. Secures string in left hand. Pulls in the doll a very little way. Transfers string to right hand. Has secured the doll from 5 inches out on table 25 seconds after the beginning of the situation. Carries to mouth. Removes to inspect. Turns it around. Transfers it from one hand to the other.

4:11 P.M. Screen is set up. Cat is put in place on the *left* with *Converging Strings*. Screen is removed. J is in position. Looking at the cat he contacts the left-hand string with his left hand. He scratches on it a little. Withdraws hand. Returns to the string. Secures it. After 10 seconds, has brought cat to about 6 inches from the edge of the table. Secures it in right hand. Also scratches on string with left hand. Scratches the string again. Brings to edge of table where he secures it 40 seconds after the beginning of the situation in his left hand. Holds out on table. Secures string again and pulls it in toward him. This time he drags it by the string off the table to the platform. Hits it about on the platform. Holding it in his hands he squeaks it and looks at it. The cat is removed, though J hangs on to the string.

4:13 P.M. Cat is put in place with *Converging Strings* correct string on the *right*. J is in position when the screen is removed. Looks at the cat. Scratches on the right-hand string. Secures it in his right hand. Pulls cat to about 6 inches from the edge of the table. Smiles at the Examiner as he secures the cat in his right hand 10 seconds after the beginning of the situation. Hits it on the table. Holds far out on the table. Transfers to left hand. Squeaks and hits it on the table with left hand. Holds it far out on the table. Holding it up by the grill, he pokes at the top of the cat with index finger of his right hand. Carries through the grill after 35 seconds. Holds out at his side. Carries to mouth. Removes the cat and coughs a little.

4:16 P.M. J peeks around the right-hand end of the screen as the next situation is prepared. The automobile is put in place with the *Roundabout and Direct Strings,* correct string coming down on the *right*. Screen is removed. He looks at the automobile. Extends right hand toward it down the middle of the table through Space *5A*. Then with left hand reaches over to the right. Secures string. Looks at the automobile as it comes in. Has contacted it 15 seconds after the beginning of the situation. Secures it also. Hits it on the table as he holds it out on table. Transfers from right to left hand, again to right. Hits on the table, holding far out. Brings to table, holding and inspecting it. Left hand goes through Space *4B*, then through Space *6A*. Holds automobile far out on the table dangling it by a bit of the string.

4:18 P.M. Automobile is removed. Starts to pull himself up to the grill. The large screen is set up in preparation for the next situation.

The automobile is put in place as before with *Roundabout and Direct Strings,* correct string coming down on the *right.* Screen is removed. J looks at the automobile. Glances over to the string on the right. Looks at the automobile as he secures the end of the right-hand string in his right hand. Transfers to left. One swift tug brings automobile to edge of the table where he contacts and secures it 10 seconds after the beginning of the situation. Secures it in his right hand, but pushes it out of hand onto table with left hand. Takes hold of string close to the automobile. Pulls through grill again 25 seconds after the beginning of the situation. Holds it, turning it around as he looks at it.

4:19 P.M. Screen is set up. Fish is put in place with *Roundabout and Direct Strings,* correct string coming down on the *left.* Automobile is removed. J is in position with the screen removed. Fish is rattled. He looked at it before it was rattled. Looks over to right-hand string. Pulls it in with right hand. Looks at the string on the left. Secures it in his left hand. One tug brings fish to 5 inches from the edge of the table. Secures fish in right hand, still holding string in left, 20 seconds after the beginning of the situation. Hits fish on the table. Carries through the grill with his left hand 30 seconds after the beginning of the situation. Carries toward mouth. Removes and inspects. Again to mouth. Vocalizes. Right-hand string was not pulled all the way in, but is still lying on the edge of the table.

4:21 P.M. Fish is removed and put in place as before with *Roundabout and Direct Strings,* correct string coming down on the *left.* Screen is removed. He looks at the fish. Reaches out far on the table with his right hand. Pulls right-hand string in. Discards on the platform. Looks at the fish. Secures left-hand string in left hand. Brings fish to about 8 inches out on the table. Secures it 20 seconds after the beginning of the situation in his left hand, having first strained for it with his right hand. He has some difficulty in getting it through the grill, but gets it through 35 seconds after the beginning of the situation. Carries to mouth. Removes and turns it around. Inspects and carries again to mouth.

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3:52 P.M. The doll is put in place on the *right* with three *Perpendicular Strings.* J is moved into position. The fish is removed. Screen is removed. He looks at the doll before it is rocked. Im-

mediately secures right-hand string in his right hand. One tug brings doll to 4 inches from table edge. Secures it in his left hand 8 seconds after the beginning of the situation. Carries through the grill and to his mouth. He is starting to pull in the median string after 25 seconds.

3:54 P.M. The screen is set up. J holds the doll in Space *6B* pushing it on the screen. The cat is put in place on the *left* with three *Perpendicular Parallel Strings.* The doll is removed. The screen is removed. He looks at the cat. Although his right hand is on the table on the median string, he does not attempt to secure the median string, but scratches on the left-hand string. As he turns momentarily to look toward the back of the room, the median string sticks to his damp hand and is pulled off the table, but apparently he did not pull it intentionally. He secures left string with his right hand after attempting with his left and pulls the cat off the table and secures it 20 seconds after the beginning of the situation. He hits it on the base of the grill. Transfers it from hand to hand. Squeaks it and drops it. Picks it up again by the string and waves it, dangling it about on the platform. Hits it again on the grill. Carries it to his mouth.

3:55 P.M. After 1 minute 5 seconds the screen is set up. The duck is put in place on the *right* with three *Oblique Parallel Strings.* J is moved into position. The cat is removed. Screen is removed. He looks at the duck. Reaches over with his right hand to the right string. Secures it. Then brings it with two tugs to 4 inches from the edge of the table. Transfers to left hand. Pulls duck through the grill and secures it from the base of the grill with his right hand 15 seconds after the beginning of the situation. Holds it in both hands, inspecting and waving it. Puts it back on the table as far as he can reach and pounds it hard on the table. Brings it back through the grill again.

3:57 P.M. After 50 seconds the screen is set up. The ball is put in place on the *right* with three *Oblique Parallel Strings.* The duck is removed. J is in position as the screen is removed. He looks at the ball. With his right hand he secures the right-hand string. Brings the ball with one tug rolling to the edge of the table where he contacts it 5 seconds after the beginning of the situation. Pursues it with his left hand. Picks it up with left hand 5 seconds later. Transfers string to left hand, releasing the ball. Takes ball in right hand. Hits it on the table, holding it far out on table. After 30

seconds brings it through the grill with his left hand. Holds it back over the table again and hits it on the table. In the course of these manipulations on the table, one of the two loose strings was dragged off—the median string.
3:59 P.M. The screen is set up. The duck is put in place on the *left* with three *Oblique Parallel Strings*. J meanwhile has pulled himself to his feet and is standing in front of the grill. He is set down and moved into position. The screen is removed. His right hand goes on the table as he looks at the doll. He secures left-hand string in his right hand after scratching at it. Brings the duck to the edge of the table and secures it 10 seconds after the beginning of the situation. Carries it to his mouth. Holds it there as he looks around the room.
4:01 P.M. The ball is put in place on the *left* with three *Oblique Parallel Strings*. J pulls himself to his feet by the left side rail. He sits down and is moved into position. The duck is removed. He is in position finally when the screen is removed. He looks at the ball. Puts hand on the left-hand string. After some scratching with his left hand, he scratches with his right hand, then left, again right. He has difficulty in the prehension of the string. It becomes entangled with the other strings. It is the left-hand string that he secures eventually. Brings ball rolling off to the platform 25 seconds after the beginning of the situation. Secures it in his right hand 5 seconds later. Dangles it about by the string as he waves his hand. Bounces it about on the platform in this way.
4:03 P.M. Doll is put in place with *Converging Strings*, correct string on the *right*. J is set in position when the screen is removed. Looks at the doll, then at end of left-hand string. While looking at the doll, he begins scratching toward the left-hand string. Does not pull it in. Picks up median string. Drops it on the table. Looks toward the left-hand string again. Does not pull it in, however, although he picks at it. Secures the right-hand string and tips the doll over as he brings the string to the median position. He pulls the right-hand string in a little farther. Picks up median string which is entirely out on table, then drops it. He is able by this time to reach the head of the doll and secures it 45 seconds after the beginning of the situation. Brings it out through the grill.
4:05 P.M. Screen is set up. Fish is put in place with *Converging Strings*, correct string on the *left*. The doll is removed. The screen is removed. He looks at the fish, then at the end of the

left-hand string. Scratches on string with his left hand. Right hand scratches on it, not well aimed at the string. The string is moved over toward the median a little. He picks up median string momentarily. Drops it without pulling it in. Renews efforts on left-hand string. Secures it in his right hand and has contacted the fish 22 seconds after the beginning of the situation, having brought it with one tug to the edge of the table. He picks it up and releases it about 2 seconds after contacting it. Later carries through the grill. Looks in bowl and pokes there.

4:06 P.M. Screen is set up. Cat is put in place on the *left* with *Converging Strings.* J is vocalizing as he mouths and also manipulates the fish. The fish is removed. The screen is removed. He looks at the cat. Scratches on the left-hand string with his left, then with his right hand, glancing at the string. His right hand is active. He secures the string and brings the cat with one tug to the edge of the table where he contacts it 12 seconds after the beginning of the situation. He picks it up with his left hand. Then stands by the left side rail, pulling at the Examiner's smock.

4:08 P.M. Screen is set up. The duck is put in place on the right, with *Converging Strings.* J pokes at the screen as he is in standing position. He is in position when the screen is removed. He looks at the duck. Right hand secures the right-hand string. Pulls it with one tug to the edge of the table. Left hand secures it 5 seconds later. He carries it through the grill to his mouth and chews on it.

4:10 P.M. Screen is set up. The fish is put in place with *Roundabout and Direct Strings,* correct string on the *right. J* is in position when the screen is removed. He looks at the fish. Extends his left hand toward the left-hand string. Pulls it in with his right hand. Then he waves it off to the right. Looks at right-hand string; secures and pulls it. Gets his left hand on fish far out on the table 25 seconds after the beginning of the situation. Carries it to the grill and brings through the grill. Pokes in the bowl with his left hand.

4:12 P.M. The screen is set up. The automobile is put in place with *Roundabout and Direct Strings,* correct string on the *right.* The fish is removed. Screen is removed. Both hands are on the table but the right hand is the active one. It secures the string and brings the fish to where the left hand far out on table contacts and secures it 8 seconds after the beginning of the situation. J holds the automobile over the table, then brings it to his mouth through Space

5B, also transfers it to his right hand. Scratches on it with his left hand.

4:13 P.M. The fish is put in place with *Roundabout and Direct Strings,* correct string on the *left.* J has dropped the automobile out of the crib. The screen is removed. He looks at the fish. Picks up the right-hand string. Drops it. Re-secures and pulls it off the table. Drops it on the platform at the left. Then he scratches at the left-hand string with his left hand. Secures it and brings the fish with one tug to the edge of the table where he contacts it 18 seconds after the beginning of the situation. Secures it 3 seconds later, carries it through the grill and inspects it.

4:15 P.M. The screen is set up. The automobile is put in place with *Roundabout and Direct Strings,* correct string on the *left.* The fish is removed. The screen is removed. J looks at the automobile. Pulls in right-hand string promptly with right hand. Drops it on the platform. Secures left-hand string with his left hand. Transfers to right. One tug brings the automobile half way across the table; then with his left hand he secures the string 2 inches from the automobile and pulls it off the table and secures it 25 seconds after the beginning of the situation.

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J's mother brings him into the reception room. He has been in an elevator full of strange people, and he seems to feel the strangeness of the situation. He cries when he is set down on the table. After a while he stops crying, and he accepts being carried into the examining room by his mother. He is held in her arms while the Examiner displays various toys to his little brother. He extends his hand toward the duck when it is placed on the platform, and his mother then sets him in the crib. He picks up the duck and plays with it. Later, he plays with the fish. He seems to be well adjusted to the situation now, and his mother and brother leave the examining room. J hands the fish to the Examiner.

[After Single-String Situation]

3:59 P.M. The screen is set up. The doll is put in place on the *right* with *Perpendicular Parallel Strings.* J pushes hard at the screen, so that it is difficult to arrange the materials. The fish is removed with some difficulty as J hangs on to the string. Then the screen is removed. J immediately secures the right-hand string in his right hand, draws the doll to the edge of the table, and secures it 5

seconds after the beginning of the situation. He carries it through the grill, holds it in both hands, takes it in his left hand momentarily, approaches the string with his right hand, then carries the doll to his mouth, removes, and sets it on the table through Space *6A*. He takes it by the head and pulls it out again, and holds it in his hands as he inspects it.

4:00 P.M. The screen is set up. J again pushes hard at the screen. The cat is in place on the *left* with *Perpendicular Parallel Strings*. J holds the string in one hand and the doll in the other, and brings his hands together. The doll is removed with some resistance. The screen is removed, revealing the cat. Both of J's hands go on the table, and secure the outside strings. The right hand drops on the platform the right-hand string which it has secured, and the left hand continues pulling the left string. He has secured the cat 8 seconds after the beginning of the situation. He carries it through the grill, and to his mouth.

4:01 P.M. The screen is set up. The duck is put in place on the *right* with *Oblique Parallel Strings*, while J pushes at the screen. The screen is removed. The cat is removed, and the duck is tapped on the table. J extends his right hand, first through Space *7B* toward the right-hand string, and then withdraws it and goes in through Space *7A*. He secures the string, pulls the duck to 5 inches from the edge of the table, reaches in, and secures it about 12 seconds after the beginning of the situation. He carries it through the grill, and inspects it. He pokes it through Space *6A*, and as far on the table as he can reach, and then draws it back. He has slid too close to the grill, and is moved back by the Examiner.

4:02 P.M. While J is playing with the duck, the screen is set up. The ball is put in place on the *right* with *Oblique Parallel Strings*. J is in position when the screen is removed. He looks at the ball, scratches on the right-hand string, has some difficulty in securing it because he is looking at the ball, but finally secures it. It snaps toward the middle of the table, and becomes involved with the median string, so that it is hard to tell which one reaches the ball. He pulls in the median string, and then secures the right-hand string, brings the ball rolling off the table to the platform, and picks it up there about 13 seconds after the beginning of the situation. He holds it dangling by a little bit of the string, as he smiles, and looks at the Examiner. He looks back at the ball as he manipulates it with his right hand. When the ball rolls away out of reach under

the table, he takes the end of the string and pulls it rolling toward him.

4:05 P.M. The screen is set up, and the duck is put in place on the *left* with *Oblique Parallel Strings*. The ball is removed. The screen is removed. J looks at the duck, and his right hand goes to the part of the table where the correct string was before. His left hand reaches for the left-hand string, and then his right hand secures it, but he releases it, and withdraws his hand. Then his left hand approaches the left-hand string, but gets hold of the median string. The pursuit is definitely for the left-hand string. However, he does pull the median string off the table as if to get it out of the way, and discards it on the platform. Then he secures the left-hand string in his left hand, and brings the duck to the edge of the table where he secures it 35 seconds after the beginning of the situation. He carries it through the grill, and vocalizes as he looks over to the right, and pulls himself up by the right side rail.

4:06 P.M. The screen is set up. The ball is put in place behind the screen with *Oblique Parallel Strings,* the correct string on the *left*. J is standing in front of the middle of the grill. He scratches at the screen, turns to the Examiner, pulling at her smock, and then scratches at the screen again. He is standing in position when the screen is removed, and since it was not possible to set him down before, he is now set down. He reaches over for the left-hand string and looks at the ball. The string snaps away from his hand, becomes involved with the median string, and he pulls the median string and right-hand string off the table, discards them on the platform, and then secures the left-hand string in his left hand; 15 seconds after the beginning of the situation, he has secured the ball. He takes the string again, however, and brings the ball rolling to the platform, and picks it up there about 25 seconds after the beginning of the situation. He holds it, dangling it by the string as he looks at it. He smiles, looks at the Examiner, pulls himself to his feet by the grill, then lowers himself, turns to the ball on the platform, takes the string, and pulls it rolling toward him. When he pulled in the loose strings this time, it was as if he were trying to clear them off the table so as to be able more effectively to secure the correct string.

4:10 P.M. The screen is set up. The doll is put in place with *Converging Strings,* the correct string on the *right*. J is pulling up the blotter, and exploring the pad underneath. He is turned around

into position. He pushes at the screen. The screen is removed. He looks at the doll. His left hand reaches for the left-hand string, but as he rubs on it, and it comes in a little way, he withdraws his hand, looks over at the right-hand string, approaches it with his right hand, then with his left hand. His left hand goes back to the left-hand string. He pulls it in a little farther—about half way in—and leaves it there on the table. His right hand secures the right-hand string, brings the doll to the edge of the table where he secures it 20 seconds after the beginning of the situation. He carries it through the grill, brings it momentarily to his mouth, removes it to inspect it, hits it on the grill, pokes it through Space *7A* onto the table, takes it by the head, brings it out again, carries it to his mouth, and chews it.

4:12 P.M. The screen is set up. The cat is put in place with *Converging Strings,* the correct string on the *left.* J is meanwhile poking the doll through the grill against the screen. The doll is removed. The screen is removed. J looks at the cat, begins scratching on the right-hand string with his right hand, pulls it in with his left hand, drops it on the platform, pulls the median string in about half way with his right hand while looking at the cat, leaves it on the table, secures the left-hand string in his left hand, brings the cat to about 4 inches from the edge of the table, and contacts it about 15 seconds after the beginning of the situation. In an attempt, apparently, to pull the cat in farther with the string, he pulls in the median string which is now leading toward the cat, then secures the left-hand string, brings the cat to the edge of the table, and there he secures it 25 seconds after the beginning of the situation. He carries it through the grill.

4:14 P.M. The screen is set up. The doll is put in place with *Converging Strings,* the correct string on the *left.* J pulls himself to his feet by the left side rail, cruising to the back of the crib. The screen is removed while he is standing at the back of the crib facing the back. He is set down into position, and his right hand immediately goes on the right-hand string as he is looking at the doll. He pulls it in only about 2 inches, however, and then looks over at the left-hand string, scratches at it with his left hand, then with his right hand, secures it, brings the doll to the edge of the table with one tug, and secures it 15 seconds after the beginning of the situation. He carries it through the grill to his mouth, momentarily bites on it, and then, fussing a little, pulls himself up by the right side rail.

The Examiner comes around and hands him the tri-colored rings. Since J still shows signs of fussing, he is picked up by the Examiner, and carried around. When an attempt is made to replace him in the crib he begins fussing, so the Examiner picks him up, carries him into the reception room, and sets him on the table. He plays with the fish, and the tri-colored rings.

4:21 P.M. J is brought back into the examining room and set in the crib. He shows a little sign of fussing. The screen is set up. The automobile is put in place with *Converging Strings,* the correct string on the *right.* The screen is removed. J is moved into position. He reaches first for the left-hand string, but does not secure it. He immediately becomes active on the right-hand string. First with his right hand, and then with his left hand, he scratches at the string. He approaches it again with his right hand, then with his left hand, and then with his right. Finally, he secures the tip of the string between the thumb and index finger, and with one tug draws the automobile to the platform 30 seconds after the beginning of the situation. He picks it up immediately, holds it in his hand, and turns it over.

4:22 P.M. Since J seems to be getting tired of the string situations, the lever board is put in place.

[After lever situation]

4:35 P.M. While J is standing at the back of the crib, the screen is set up, and the fish is put in place with *Roundabout and Direct Strings,* the correct string on the *right.* The screen is removed. The bell is removed. J is set down into position. He sounds a little fussy, but not heartily so. He looks at the fish for about 5 seconds, and then reaches for the left-hand string with his left hand. When he has pulled it in, he looks at it, drops it on the platform, turns to the left side rail pulling himself up to his knees, then begins pulling up the blotter on the left, turns to the right, and pulls up the blotter there. The fish is left on the table with the right-hand string untouched.

4:39 P.M. The automobile is put in place behind the screen, with *Roundabout and Direct Strings,* the correct string on the *right.* The screen is removed while J is standing, tugging at the Examiner. He is set down, and moved into position. The automobile is tapped on the table. He looks at it, scratches at the platform a little with his right hand, and brings the automobile with one tug to 3 inches

from the edge of the table, where he secures it 15 seconds after the beginning of the situation. He carries it through the grill, holds the automobile in one hand and the string in the other as he extends his left hand holding the automobile toward the Examiner. Standing by the left side rail, he dangles the automobile by the string.

4:41 P.M. The automobile is removed, and put in place with *Roundabout and Direct Strings,* the correct string on the *left.* J is vocalizing a little protestingly. The screen is removed as he is standing by the left side rail, facing the Examiner. He pokes the Examiner's lips with his right index finger. He is set down, and moved into position. He leans over and pulls at the blotter, but is set in position again by the Examiner. When the automobile is tapped on the table, he looks down at the right-hand string, secures it in his right hand, pulls it in, and drops it. He secures the left-hand string in his left hand, brings the automobile to the edge of the table, and secures it 25 seconds after the beginning of the situation. He carries it through the grill, and turns it around, inspecting it. His vocalization sounds rather sad.

4:44 P.M. The examination is concluded.

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LA CROISSANCE DE L'ADAPTATION DANS LE COMPORTEMENT DES JEUNES ENFANTS

(Résumé)

Dans cette investigation on a étudié le développement de l'adaptation dans le comportement des jeunes enfants au moyen de problèmes qui exigent l'utilisation d'une ficelle pour obtenir un "appât" autrement inaccessible. Les sujets ont été 16 enfants de familles supérieures, observés à intervalles de quatre semaines depuis l'âge de 28 semaines jusqu'à l'âge de 52 semaines, dans un total de 88 examens. On a montré les situations sur le haut d'une table, ordinairement derrière une grille. On a présenté d'abord des situations d'une seule ficelle avec la grille en position et on les a présentées de nouveau sans la grille dans les cas d'insuccès. On a présenté des situations de plusieurs ficelles avec la grille en position, lesquelles ont offert des ficelles non attachées avec la ficelle attachée, après le succès dans le premier groupe de situations d'une seule ficelle. Les situations de plusieurs ficelles ont été de quatre types, formant une série progressive: trois ficelles parallèles perpendiculaires; trois ficelles parallèles obliques; trois ficelles convergentes; une ficelle indirecte et une ficelle directe.

Dans les situations d'une seule ficelle à 28 et à 32 semaines la grille a été un obstacle mécanique et visuel au succès. A 44 semaines son influence a été négligeable. Entre 28 et 44 semaines le pourcentage de succès dans la situation d'une seule ficelle avec la grille s'est élevé de 3 à 100. Le développement de la capacité motrice et celui de l'attitude perceptive a marqué cette période. La "compréhension" de l'utilité de la ficelle a semblé être plus grande avec l'avancement de l'âge. Les succès qui ont semblé être accompagnés de peu de compréhension ou d'aucune compréhension ont été presque entièrement limités à la situation sans la grille, à 28 et à 32 semaines. Ainsi dans cette situation la capacité motrice d'atteindre l'appât semble quelquefois précéder l'attitude perceptive. Avec la grille en position, on n'a obtenu l'appât que très rarement sans évidence d'une vraie utilisation de la ficelle comme moyen de l'atteindre. Dans cette situation, en effet, à 32 et à 36 semaines la perception a semblé précéder quelquefois la capacité motrice. Le temps nécessaire pour tirer l'appât à portée s'est montré en relation avec l'attitude perceptive ainsi qu'avec la capacité motrice.

Dans les situations de plusieurs ficelles le choix de la ficelle tirée premièrement a semblé dépendre (a) de la forme visuelle présentée par l'appât et les ficelles avec l'appât comme l'élément dominant; (b) des tendances à étendre la main dans une direction donnée ou à étendre une main donnée: et (c) de la présence ou de l'absence de facteurs plus généraux qui empêchent, tel que l'impulsion à l'activité locomotrice. Les habitudes de position montrées n'ont été accompagnées que de temps en temps d'une grande évidence d'un emploi de la main correspondante et ont montré quelquefois un changement de la main étendue avec le maintien de la direction préférée de l'étendre.

RICHARDSON

DIE ENTWICKLUNG DER ANPASSUNGSFÄHIGKEIT BEI SÄUGLINGEN

(Referat)

In dieser Forschung untersuchte man die Entwicklung des Anpassungsfähigkeit von Säuglingen (adaptive behavior of infants) durch Gebrauch von Aufgaben, die die Verwendung einer Schnur zur Erreichung eines sonst unerlangbaren Reizes (lure) in Anspruch nahmen. Als Versuchspersonen dienten 16 Säuglinge aus überlegenen Heimen. Diese Kinder wurden im Alter von 28 bis zu 52 Wochen alle vier Monaten beobachtet. Im Ganzen wurden 88 Untersuchungen gemacht. Die Situationen wurden auf einer Tischfläche, gewöhnlich hinter einem Gitter, entfaltet. Zuerst wurden Situationen mit Verwendung einer einzelnen Schnur und mit dem Gitter dargeboten. Diese wurden im Falle eines Misserfolgs dann ohne Gitter wiedergegeben. Nach Erfolg mit der ersten Situationsserie mit einer Schnur (single-string situations) wurden Situationen mit mehreren Schnüren vorgestellt, worin das Gitter an seiner Platz war und worin lose Schnüre mit der angebundenen Schnur zusammen dargeboten wurden. Die Situationen mit mehreren Schnüren waren von vier Sorten die eine abgestufte Serie bildeten: drei senkrechte, parallele Schnüre; drei schräge parallele Schnüre; drei konvergierende Schnüre; und eine weitläufige und eine direkte Schnur.

In den Situationen mit einer Schnur war des Gitter bei 28 und bei 32 Wochen sowohl ein mechanisches wie eine visuelles Hinderniss gegen den Erfolg. Mit 44 Wochen war die Einwirkung des Gitters unbedeutend. Zwischen 28 und 44 Wochen stieg der Prozentsatz der Erfolge bei der Situation-mit-einer-Schnur von 3 bis auf 100. Dieser Zeitraum zeigte sich durch Entwicklung sowohl der motorischen Fähigkeit wie der perzeptiven Einstellung aus. Einsicht ("insight") in die Nützlichkeit der Schnur schien mit zunehmendem Alter in zunehmendem Grade anwesend zu sein. Erfolge die mit wenig Einsicht einhergingen oder ohne Einsicht Stattfanden waren fast ganz auf die Situation ohne Gitter, bei 28 und 32 Wochen, beschränkt. In dieser Situation, also, schien die motorische Fähigkeit, den Reiz erreichbar zu machen, manchmal der perzeptiven Einstellung (perceptive attitude) vorauszugehen. Wenn das Gitter an seiner Stelle war, konnte der Reiz nicht leicht erreicht werden ohne Beweis zu liefern, dass die Schnur bestimmt verwendet worden war, um den Reiz erlangbar zu machen. In dieser Situation, mit 32 und 36 Wochen, schien die Perzeption (perception) manchmal sogar der motorischen Fähigkeit (motor ability) vorauszugehen. Die Zeit die nötig war, um den Reiz mit der Schnur ergreifbar zu machen erwies sich als sowohl mit der perzeptiven Einstellung wie mit der motorischen Fähigkeit verbunden.

In den Situationen mit mehreren Stricken schien die Wahl der Schnur für den ersten Zug (initial pulling) auf folgende Einwirkungen zu beruhen: a) auf die durch den Reiz und die Schnüre dargebotene visuelle Gestalt (pattern), worin der Reiz der herrschende Bestandteil war; b) auf Neigungen, nach einer bestimmten Richtung oder mit einer bestimmten Hand zu langen; und c) auf die Gegenwärt oder die Abwesenheit mehr allgemeiner störender Einwirkungen, wie zum Beispiel des Drangs nach Bewegungstätigkeit. Die Stellungsgewohnheiten (position habits) die sich gelegentlich zeigten gingen nur dann und wann mit starkem Beweis entsprechender Händigkeit (handedness) einher und nahmen manchmal eine Wechslung der langenden Hand, unter Erhaltung der bevorzugten Richtung des Langes in Anspruch.

RICHARDSON

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GENETIC PSYCHOLOGY MONOGRAPHS

Child Behavior, Animal Behavior, and Comparative Psychology

DIFFERENTIAL REACTIONS TO TASTE AND TEMPERATURE STIMULI IN NEWBORN INFANTS*

From the Department of Psychology of The Ohio State University

BY

KAI JENSEN

*Recommended for publication by George F. Arps and accepted for publication by Carl Murchison of the Editorial Board.

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CONTENTS

I

INTRODUCTION

The Problem

The absence of language responses in the newborn infant has restricted the investigation of just those problems which are the basis of adult behavior. If some substitute for such responses could be secured, a new field of inquiry would be opened and light shed on many problems which had not even been formulated.

In seeking an objective procedure which might serve, at least as a partial substitute for such language behavior, a new experimental technique was developed which involves the use of a fundamental behavior mechanism, the feeding reaction, as an indicator of the infant's responses to controlled stimulation. This technique consists in comparing sucking reactions to various experimental stimuli with a control sucking reaction, all curves being objectively recorded. The controls being identical, any deviation from the control curve by the experimental curve was interpreted and described as a differential reaction.

Historical Review

Although the feeding reaction is an important one for all animals, it has received relatively little attention. This is due perhaps partly to the difficulty of studying it objectively and partly to its very essentialness and universality which have led to its being taken for granted and have obscured it as a real problem for

study. Thus Herrick (15) (1928) writes, "The mechanisms involved in these processes (taking of food) are inborn and require no practice for their perfect performance. They are innate, invariable, and essentially similar in all members of a race or species" (p. 87).

Sucking. Preyer (29) (1901) has pointed out that "sucking belongs to the earliest coordinated movements of man; it is associated directly with swallowing, and has been repeatedly perceived even before the child was fully born" (p. 257). Indeed, Feldman (13) (1920) points out that the act is theoretically possible after the third month of fetal life.

Irwin (17) (1930) remarks: "Sucking is a pattern which is highly organized from the first. Provided the infant has not been fed recently, though occasionally even after feeding, it is readily evoked by a light touch about the mouth region. Under the conditions of the experimental chamber, sucking appears when the fingers of the infant slash by the face or when in its head movements the lips brush against a sleeve or article of bedding. Not infrequently sucking appears without external stimulation or contacts. During hunger periods, when there is much head rolling and when the mouth and jaws are engaged in what some have called 'seeking movements,' sucking will occur without external contact. It is then accompanied by much licking of the lips and by smacking sounds. It may be that the condition of the membranes of the mouth, in this case, evokes sucking" (pp. 61-62).

Allix (2) (1867), Burdack (9) (1888), and Hertz

(16) (1865) hold that the negative pressure inside the oral cavity which is essential for sucking is produced by inspiratory suction. Biedert (7) (1875) maintains that the suction in the mouth is produced by the descent of the lower jaw which increases the diameter of the mouth cavity in the dorso-ventral direction.

Auerbach (3) (1888), after a careful investigation, distinguished two different kinds of suction:

1. Inspiratory suction—chiefly in the case of adults.
2. Suction as the result of the depression of the lower jaw, and contraction of the tongue (this type he designated the infantile type).

Murlin (22) (1923) has pointed out that the second type is often employed by adults as in smoking a pipe.

Auerbach (3) (1888) believes that change in the form of the tongue and movements of the tongue itself do not materially influence sucking, but Basch (5) (1893) and Pfaundler (26) (1899) regard such changes as important features of the sucking reaction.

Hertz (16) (1865), Biedert (7) (1875), Pfaundler (26) (1899), Cramer (11) (1900), Basch (6) (1894), and Barth (4) (1914) measured the negative pressure created by infants in sucking milk. This was found to be 4-15 cm. Hg. by Hertz and Basch, 10-70 cm. H_2O by Pfaundler, and from 58-140 cm. H_2O by Cramer.

Litinski's (21) (1902) results were:

Age of infant	Suction energy
2-7 days	35-40 cm. H_2O
older	45-51 cm. H_2O
a few months	24-43 cm. H_2O

Kashara (18) (1916) is the only experimenter to record suction curves. Two glass tubes, 5 mm. in diameter, were inserted into the rubber stopper of a 100- to 150-cc. nursing bottle in such a manner that one was immersed in the liquid in the bottle and the other open to the air inside. The tube open to the air was connected to a Marey's tambour and the other to a nipple through which the infant sucked its milk. He "examined 75 infants in good health under artificial feeding" (p. 75).

His experimental procedure was as follows:

"Milk of a certain temperature was put into the nursing bottle, and an infant was permitted to suck at the nipple, with the result that every change in pressure in the oral cavity was given to Marey's tambour and was registered on the blackened paper closely attached to the kymograph. Jaquet's watch was used to measure the speed of the registering tube which was turning around. The child was put on its mother's knee, a little aslant in posture, with the kymograph back of the mother. The kymograph should be as noiseless as can be obtained. By this experiment were obtained the curved lines which I call curved lines of suction."

According to Kashara these curved lines of suction have four characteristics: "1. The descending part of the curve represents the downward movement of the lower jawbone, the oral cavity being extended in the vertical diameter. 2. The small elevation is due to the pressure on the nipple attached to the rubber tube. 3. The ascending part of the curve may be attributed

to the running down of the milk which has been taken into the mouth. 4. The notch is a concave curve caused by the swallowing" (p. 75).

Kashara reaches the following conclusions:

"1. The curved lines of suction made by infants in good health are always regular and never discontinued.

"2. When an infant in good health sucks and swallows milk, the time ratio of the two acts is 1 to 1, or rarely, 2 to 1.

"3. In the case of a newborn baby, the curved lines of suction are discontinued now and then for physiologic reasons. In this case there is a certain pause between regular curved lines of suction.

"4. Infants of premature birth or in atrophy make very irregular curved lines of suction, and often discontinue them, but the lines gradually become regular again when the state of nutrition is improved.

"5. Certain diseases of the mouth, nasal catarrh, and acute atitis, etc., make the curved lines of suction irregular, but they become regular again when the diseases are cured.

"6. The curved lines of suction will become irregular when the temperature of the milk is below 20° or above 40°.

"7. Idiots are unskilful in suction, and so the curved lines are always irregular."

In some cases the sucking reaction is absent. In such instances the infant either dies from starvation or is fed by means of a tube. Much more frequently the sucking reaction is only imperfectly present. Kashara's conclusions 3, 4, 5, 6, and 7 above are instances.

Abt (1) (1923) has summarized other factors producing poor sucking. He lists (1) birth injuries to the face in babies born by the face or breech presentation, (2) injuries to the baby's tongue in the Smelie-Veit extraction of the head, (3) birth injuries to the muscles of mastication, (4) injuries to the facial nerves causing temporary paralysis, (5) intracranial hemorrhages causing general somnolence, (6) drowsiness and fatigue due to general birth trauma without special localization, (7) cleft palate, (8) stomatitis, (9) acutely inflamed adenoids, and (10) the snuffles of congenital syphilis.

Preyer (29) (1901) points out that conditions must be appropriate if the response is to be elicited, "for it is not any object whatever put into the mouth that is sucked, but only certain objects, not too large, not too rough, not too hot or too cold, and not of a strongly bitter, or sour, or salt taste" (p. 261).

If there is no mechanical difficulty sufficient to account for poor nursing, it is usually regarded as an indication of an imperfect nervous system. Abt (1) (1923) writes: "Cramer, Rosenstern, Finkelstein, and others think that in these babies there is a defective development in the reflex arc of the sucking mechanism" (p. 301).

Kashara (18) (1916) concluded that "imbecile children always make irregular curves because of the imperfect coordination of the sucking movements."

Blanton (8) (1917), in discussing sucking and swallowing, writes: "Nothing but the most marked retardation or injury seems to affect this reflex. Swal-

lowing, and sucking, tongue, lip, and cheek reflexes make up the feeding reflex. The evidence is strongly in favor of the fact that weakness in ability to swallow is at least suggestive of mental retardation, whereas sucking is present at birth in most infants."

In Pratt's (27) (1930) experiments on sucking "four different areas of the face were lightly touched with the forefinger: (*a*) the cheek nearest the experimenter, about 2 inches from the corner of the infant's mouth, (*b*) a spot just below the lips on the chin, (*c*) a spot just above the lips, under the nose, (*d*) the lips themselves."

He continues: "This was one of the earlier experiments and no report was made of any specific reactions other than those of sucking. Where sucking did not occur to stimulation, 'no reaction' was reported. No careful check was kept on the number of infants for this particular reaction. The approximate number of infants was twenty" (p. 202).

Pratt (27) (1930) found "that a comparison between asleep and awake shows the reaction occurring most frequently while awake. However, if the reaction depends on the length of the interval between the last feeding and the time of stimulation, this is to be expected, since the probability of being awake becomes greater as the next feeding period approaches. When both conditions, asleep and awake, are combined, the frequency of the sucking reaction occurs in the following order: direct stimulation of lips 55 per cent; stimulation above lips 34 per cent; below lips 15 per cent; on cheeks 10 per cent" (p. 204). He concludes: "The

facts seem to justify the conclusion that the most frequent activity of the infant at birth is that of sucking. Thermal, gustatory, and also olfactory forms of stimulation release sucking reactions. For sugar solutions these reactions increase from the time of birth on, but for the temperature stimuli, the olfactory, and the remaining taste stimuli, the sucking reactions decrease as the infant becomes older. The facial reactions, the body reactions, and the reactions of the extremities, on the other hand, increase for some of the stimuli from birth on. This means that with increasing age the stimulus for sucking becomes more specific" (p. 205).

Summary

1. Sucking is one of the earliest coordinated reactions of the newborn infant.
2. The nervous mechanism for sucking is present after the third month of fetal life.
3. The negative pressure involved in sucking in the newborn infant occurs as the result of the depression of the lower jaw and contractions of the tongue and is not inspiratory in character.
4. The negative pressure created by the infants in sucking milk varies from 10-140 cm. H_2O.
5. Only one experimenter [Kashara (18) (1916)] has recorded sucking curves. His technique and results are given.
6. The physiological and mechanical conditions which interfere with sucking are given.
7. Deficiency in sucking which is not due to mechanical conditions is considered an indication of an imperfect nervous system.

8. The most frequent activity of the infant at birth is that of sucking.

9. Thermal, gustatory, and also olfactory forms of stimulation release sucking reactions.

10. With increasing age the stimulus for sucking becomes more specific.

Taste. A good review of the literature on taste experiments is given by Nelson (23, 27) (1928, 1930). She reviews the work of Kussmaul (20) (1859), Preyer (28) (1888), Kroner (19) (1881), Shinn (30) (1900), Peterson and Rainey (25) (1910), Canestrini (10) (1913), Blanton (8) (1917), and Drummond (12) (1921).

All of the above except Canestrini used facial expressions as criteria of taste reactions. Kroner, Kussmaul, Genzmer, Preyer, and Peterson and Rainey found the taste mechanism well developed and that taste stimuli, for the most part, produce facial expressions in the infant which correspond to those of the adult. Shinn and Blanton believe the sense of taste to be in an almost dormant condition in newborn infants. Drummond concludes that facial reactions to taste stimuli are products of the intensity of the stimulus used.

Canestrini (10) (1913) is the only experimenter to use the strict experimental method in studying taste reactions. He used fontanelle and breathing curves as indications of the infant's sensitivity to taste stimuli. The fontanelle curves were secured by attaching a modified Marey pneumograph to the large fontanelle of the infant; the breathing curves by placing a small pneumograph on its abdomen. The curves were

recorded upon a smoked drum. The time was recorded in half-seconds. The time of stimulation also appeared upon the record.

Canestrini (10) (1913) experimented with sweet (2- to 5-per-cent sugar solution), sour (2- to 5-per-cent vinegar solution), salt (2-per-cent solution), bitter (2-per-cent quinine solution), diluted cow's milk, mother's milk, and air. He obtained the following results:

1. Sweet stimulation produced a quieting effect upon the infant. This is shown by the lowered height of both respiratory and brain-volume curves.

2. Salt solution resulted in some restlessness and cessation of sucking movements.

3. Sour and bitter solutions caused a very marked restlessness indicated by decided irregularity in the breathing and fontanelle curves.

4. No differential reaction to cow's milk and mother's milk occurred.

5. Every sucking action is accompanied by a regular rise and fall in the brain-volume curve, due to venous stasis, produced by compression of the blood vessels.

6. The reaction-time for taste is less than for the other sensory stimuli.

7. The sense of taste is the best developed of the infant's senses.

Nelson (27) (1930) presented 227 taste stimuli to 28 infants. "The method of stimulation used in this research was that of inserting into the infant's mouth an applicator which had been dipped into the taste solution. It was found that a light touch at either cor-

ner of the infant's mouth would cause him to open his mouth, and the applicator could then easily be inserted. The applicators used were the usual round stick nursery applicators around one end of each of which was rolled a small bit of absorbent cotton" (p. 109).

The following concentrations of taste solutions were used:

Sugar 5 g., water 30 g.	16.66%
Salt 5 g., water 60 g.	8.33%
Quinine 3 g., water 120 g.	.25%
Citric acid 3 g., water 140 g.	2.14%

Distilled water was used as a control.

She found: "The sucking reactions comprise 50 per cent of the reactions to sugar, 40 per cent of those to salt, 33 per cent of those to quinine, 32 per cent of those to water, and 23 per cent of those to citric acid" (23, p. 99). "That sugar and water produce the smallest number of reactions to taste stimuli" (23, p.109). "That of all the reactions reported for the taste stimuli, 25 per cent are for citric acid, 24 per cent for quinine, 19 per cent for sugar, 17 per cent for salt, and 15 per cent for water" (23, p.114). "When sucking is excluded, the infants reacted least to stimulation with water and sugar" (23, p.126). "The most frequent reactions (to sugar) are sucking reactions. They constitute 49 per cent of all the reactions to sugar stimulation" (23, p. 126). "Of the reactions to salt, 36 per cent are sucking reactions, 16 per cent are mouth reactions, and 19 per cent facial reactions" (23, p.126).

Temperature. Genzmer (14) (1873), Kroner (19) (1881), Preyer (28) (1888), Tanner (31) (1904),

Canestrini (10) (1913), Kashara (18) (1916), Blanton (8) (1917), Drummond (12) (1921), and Peiper (24) (1924) all found that newborn infants react to temperature stimuli. Only Canestrini, Kashara, and Peiper used strict experimental procedures. Canestrini found that of all tactual stimuli used—touching certain parts of the body with the fingers, touching certain parts of the body with an applicator, touching the lips with various objects, cold stimulation with ethylchloride, alcohol, cold metal, blowing upon the infant, pin pricks, galvanic current (up to 10 milliamperes)—cold stimuli produced the most prompt and most pronounced reactions as evidenced by increased respiration, increased brain volume, restlessness, and occasionally increased pulse rate.

Peiper (24) (1924) found that the reactions of infants to cold stimulation were very pronounced as shown by irregularity of the breathing curves.

Only Kashara (18) (1916) and Nelson (23, 27) (1928, 1930) used varying degrees of temperature in stimulating the infants.

Kashara (18) (1916), using the technique previously described under the section on sucking, reported that "the curved lines of suction will become irregular when the temperature of the milk is below 20° or above 40° C."

In Nelson's (23) (1928) experiments on reactions to thermal stimulation "the technique of applying these stimuli was that of filling the dropper with distilled water at the temperature of the given compartment, opening the infant's mouth by a gentle pressure on its

skin, and then dropping from five to six drops of water on the tongue of the opened mouth by pressing on the rubber end of the dropper" (p. 59).

She was forced to abandon the objective stabilimeter technique in her experiments both with temperature and taste. "Since, in the experimental technique used for the temperature and taste stimuli, it was necessary to touch the infant, and since this touching transmitted movement to the stabilimeter records, it was found necessary to exclude the stabilimeter records in the analysis of these two tests. The analysis of these two is an analysis of the experimenter's protocols" (p. 55).

Thirty infants were given 222 temperature stimulations. The temperatures used were 8, 13, 18, 23, 33, 43, 48, and 53° Centigrade. Nelson found:

"That the largest number of specific reactions were released by the temperatures 8, 13, 18, 23, 48, and 53°; the least by 33 and 43°" (p. 65). "That at the age of 2 to 4 days, 90 per cent of the infants reacted to the temperature stimuli. That they reacted in 100 per cent of the cases to the temperature of 8° C." (p. 66). "That the temperature 43° stimulated them least" (p. 67). "At this age level (8-10 days) none of the temperatures released 100 per cent responses" (p. 69). "That the infants reacted less strongly to the temperatures which are warmer than body temperature than to those which are colder" (p. 80). "That the largest number of 'no reactions' was recorded for the temperature 43°; in other words, this temperature was the least stimulating" (p. 81). "That the least amount of specific movement is between 33 and 48°" (27, p. 161).

"That the reactions are least for the temperature 43° and greatest for the lowest temperature, 8° C." (27, p. 162).

General conclusion. The literature contains no reports of objective differential reactions to taste and temperature stimuli in the newborn. Nowhere has use been made of the coordinations involved in sucking and swallowing as a measure of the effects produced by the stimulation of the newborn infant with various tastes and temperatures. Indeed, Pratt, Nelson, and Sun (27) (1930), who have done one of the best pieces of work with newborn infants, state: "Moreover, the sucking reaction cannot be taken as the criterion of sensitivity to taste substances, since all solutions, and even a touch upon the lip areas will release sucking reactions" (p. 107).

II

APPARATUS AND PROCEDURE

APPARATUS

Development. The original apparatus designed for this investigation involved the use of the Robert's micromanometer principle with manual following of the movements of the bubble which is the indicator in this method. This type of micromanometer is sensitive to 1×10^{-4} mm. of mercury. It was planned to have the manually operated pointer connected with the mechanical pens of the polygraph and to automatic work adders.

Preliminary work revealed that the oscillatory movement involved in the present research, with its constant displacement in one direction, had a tendency to throw the bubble off center so that it did not return to zero. Also the pressures involved were such as to require an impracticably long tube.

Several arrangements were designed to make possible a short bubble tube but none proved completely satisfactory. A device was finally hit upon which permitted of the use of a very narrow tube for the bubble and still kept the length of the tube within practicable limits. This consisted in using a large U-tube in parallel with the small bubble tube. Since the negative pressure-volume studied acted on the column of water in both tubes, both were raised to the same level, but because the auxiliary tube was of large diameter, the water was not lifted very far. Be-

cause the water in the small tube traveled the same distance as that in the large, the total excursion of the bubble was easily regulated by regulating the size of the auxiliary tube used. To make the arrangement flexible several auxiliary tubes were installed with a system of stop-cocks, making it possible to cut in or out any desired number of auxiliary tubes. This design solved the problem of extent of bubble excursion, but it was found that the bubble still had a tendency to creep from the zero point.

It then occurred to the investigator that if the bubble were located at the top of the column of water, the tendency to creep would be eliminated. Also a bubble of any size could be used, which would greatly simplify the pressure reducing problem.

It now became apparent that a cork floating on the water could replace the air bubble and, properly equipped with fine aluminum wire, would replace the original hand-manipulated bubble follower. Such an arrangement, however, was not adapted to the polygraph.

For a time the writer thought of permitting the cork or an opaque liquid to interrupt a beam of light recording on photographic film. Such an arrangement, however, is quite costly and not suited to pressure-volume changes which are not merely oscillatory in character.

In seeking to convert the cork arrangement for polygraph recording a rubber tambour was connected with the open end of the manometer. This arrangement did away with manual following, made possible the use of the polygraph and was fairly satisfactory.

Rubber tambours, however, do not give equal increases in pen excursion with progressively equal increases in pressure. Also the rubber decays and must be replaced. In replacing it, it is virtually impossible to get the same tension as before. This means that constant input will result in varying records.

This difficulty was overcome by substituting a 3-inch low-pressure metal bellows of 15 flanges for the rubber tambour. This gave a constant record from day to day and progressively equal increases in pressure resulted in equal increases in record over the range used in this research. The perfected apparatus is described in the following section.

FIGURE 1

FRONT VIEW OF THE APPARATUS SHOWING MOUNTING, HOUSING OF THE DELICATE PARTS, LIGHTING, AND RELATION BETWEEN MANOMETERS AND RECORDING SYSTEM

Details are given in Figures 2, 3, 4, 5, and 6.

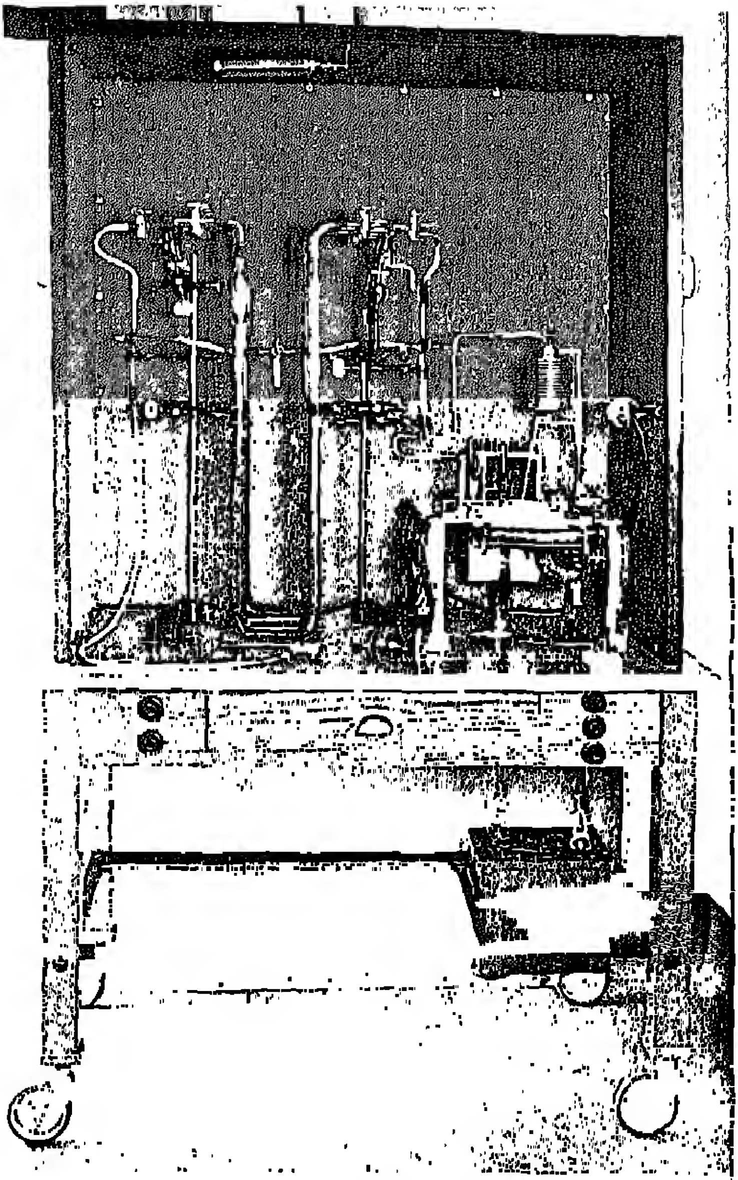


FIGURE I

FIGURE 2

Manometer and Polygraph Connections

A. Special feeding bottle, details in Figure 6.
B. Stop-cock manifold, details in Figure 5.
C. Manometer tube system, details in Figure 4.
D. Complete recording unit, details in Figure 3.
1. Telegraph key for recording special reactions.
2. Automatic safety switch for 110-volt-A.C. circuit to lights and motor of polygraph. This switch is automatically opened when cover of protecting hood is placed in position.
3. Double-throw switch for 6-volt battery circuit to recording pen magnets and special interval timer.
4. Side outlet in wall through which tube to nursing bottle is passed. In this figure the tube is shown going to the bottle without passing through the outlet.
5. Three-way T-bore stop-cock. Upper outlet to left-hand manifold of one-way manometer stop-cocks; right-side outlet to stop-cock *6*, this figure; lower opening to special feeding bottle.
6. Three-way T-bore stop-cock. Left-side outlet to *5*, this figure; right-side outlet to *7*, this figure; bottom outlet to air.
7. Three-way T-bore stop-cock. Upper outlet to stop-cock *2*, Figure 5; left-side outlet to air or nursing bottle; bottom outlet to metal bellows or tambour.

Stop-cocks *5*, *6*, and *7* can be set so that the negative pressure involved (1) passes directly to the tambour or bellows or (2) passes through the manometer and recording systems. When set for direct air transmission, opening stop-cock *6*, this figure, returns the entire system to zero reading. When the negative pressure is transmitted through the manometer system, (1) stop-cock *5* may be used to release the pressure in the nursing bottle without disturbing the pressure in the balance of the system; (2) stop-cock *7* may be used to return the tambour and metal bellows pens to zero without disturbing the remainder of the system; (3) stop-cocks *6* and *7* used simultaneously return the metal bellows, tambour, manometer, and nursing bottle to zero reading.

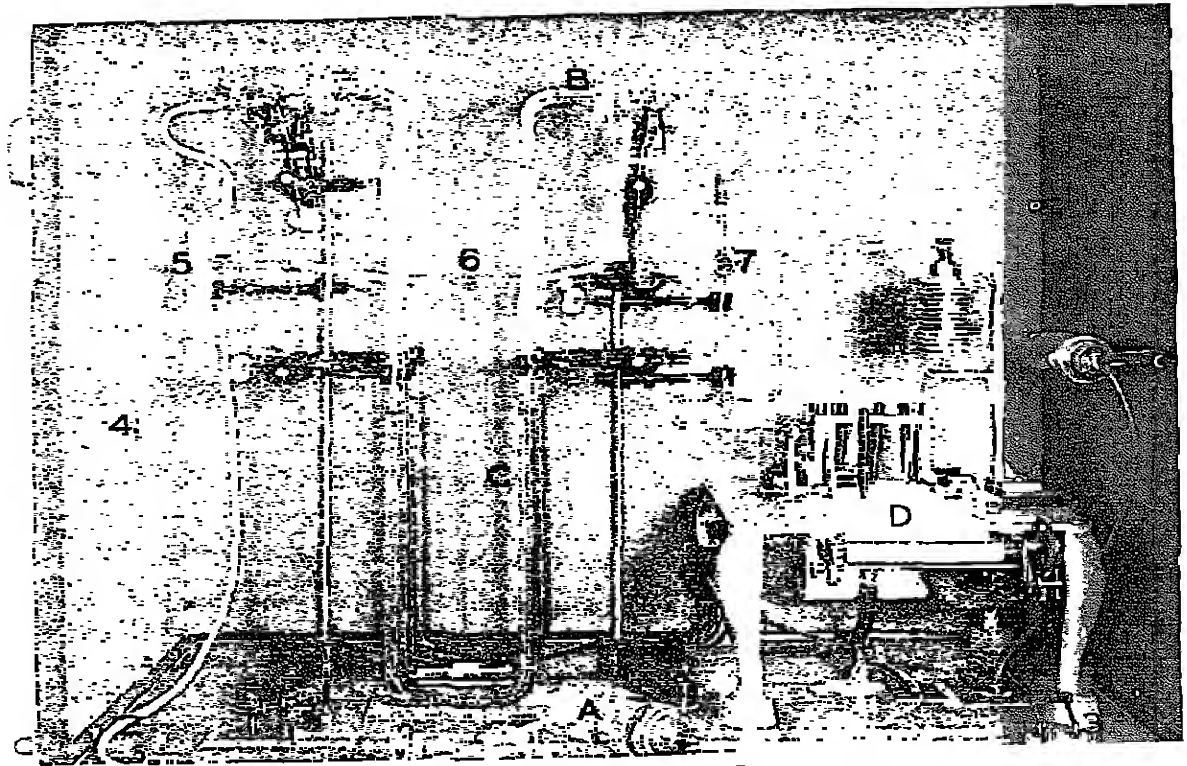


FIGURE 2

FIGURE 3

COMPLETE RECORDING UNIT: POLYGRAPH, BELLOWS, TAMBOUR

1. Hooded 25-watt finger-globe lamp for illuminating recorder tape.

2. Special bracket for insulating bellows (*3*, this figure) from motor vibrations.

3. Bellows. Three-inch low-pressure metal bellows of 15 flanges. (Cook Electric Co., Chicago.) Top outlet in bellows goes to stop-cock No. 1, Figure 4.

4. Bellows support. Metal bracket, two adjustable arms for regulating magnification range of Bristol barographic recording pen.

5. Tambour. Large size, adjustable. Used at first as a check on bellows and later for breathing record.

6. Time and stimulus marker pens.

7. Bristol barographic pen used for recording sucking curves.

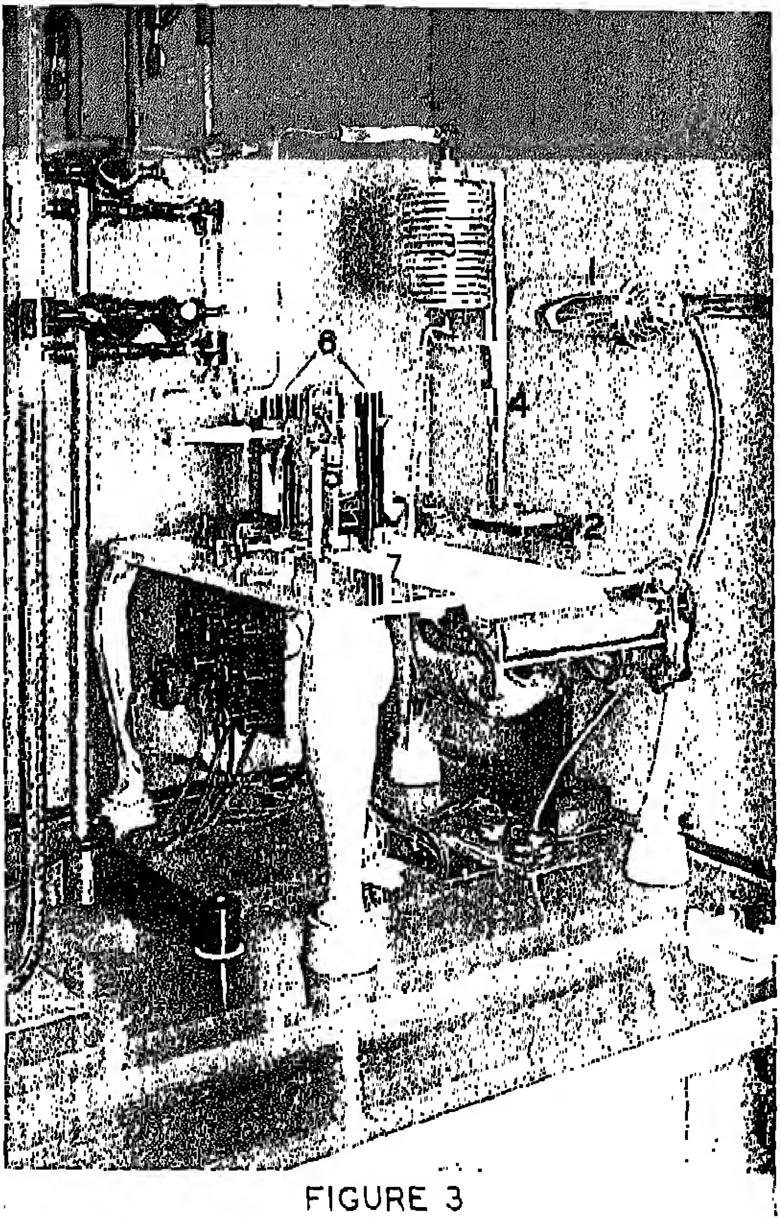


FIGURE 3

FIGURE 4

Manometer Tube System

1. Three-way T-bore stop-cock. Upper outlet to manometers; right-side outlet to metal bellows; left-side outlet to tambour.

2. Three-way T-bore stop-cock. Upper outlet to stop-cock *2*, Figure 5; left-side outlet to air or nursing bottle; bottom outlet to stop-cock, metal bellows, or tambour.

3. Manometer made from 100-cc. burette tube. Used for recording pressure-volume.

4. Manometer made from 50-cc. burette tube. Used for supplementing manometer *3*, this figure.

5 and *6*. Auxiliary manometer tubes for reducing excessive amplitude in record.

7. Enlarged section of manometer tube used to safeguard against drawing water into nursing bottle.

8. System of five one-way stop-cocks for cutting in desired number of manometer tubes.

9. Three-way T-bore stop-cock. For description see *5*, Figure 2.

10. Three-way T-bore stop-cock. For description see *6*, Figure 2.

B. These connections are described in Figure 5.

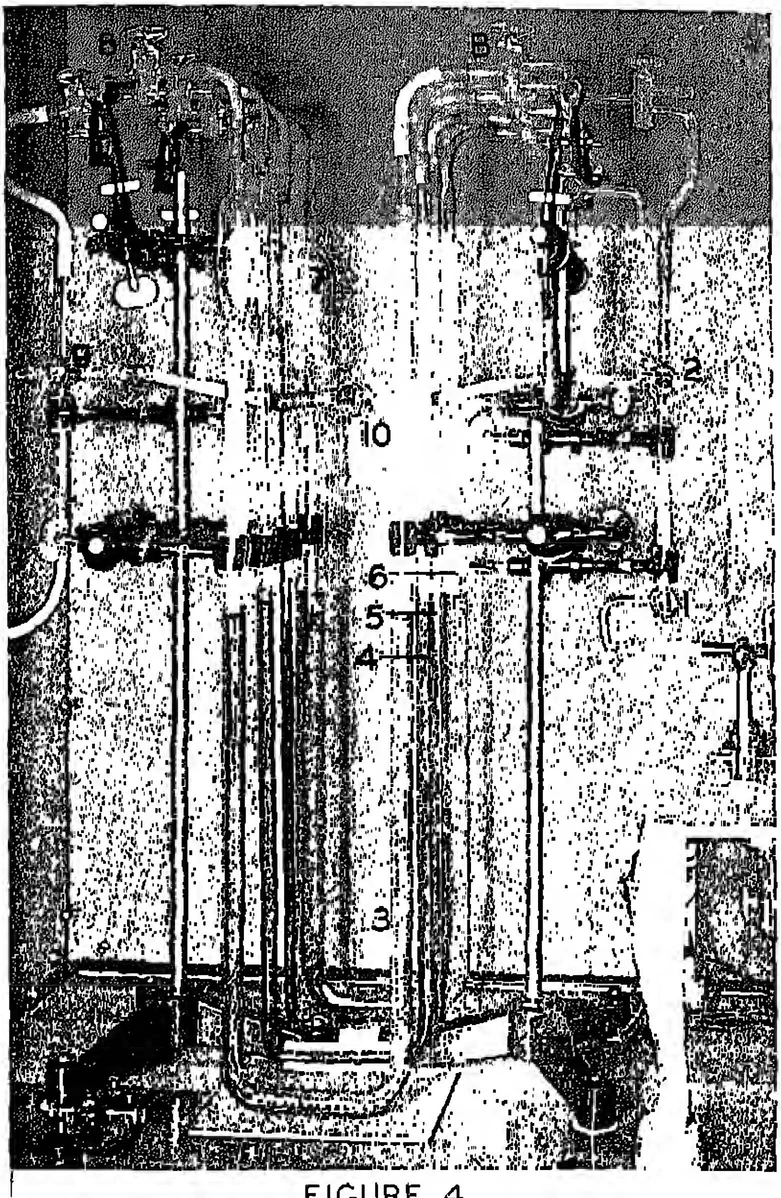


FIGURE 4

Manometer Tube System. Two of the manometers were constructed of accurately calibrated burettes, making it possible to take direct pressure-volume readings at all times, to calibrate all nipples used, and to calibrate the recording system. The other two manometers were calibrated in terms of the graduated manometers so that pressure-volume readings could always be made, regardless of the manometer arrangement used, by multiplying the reading on Manometer I, or the actual record on the polygraph tape, by a correction factor empirically determined.

TABLE OF CORRECTION FACTORS

Manometer	Correction factor
I	0.0000
I and II	1.5625
I and III	1.3158
I and IV	3.1250
I, II, and III	1.9230
I, II, III, and IV	3.1250

By manipulating the stop-cocks governing the manometer tubes it is possible to get 2080 different amplitudes for a constant input. This makes the arrangement very flexible and makes it possible to secure just the right degree of amplitude for each infant studied. It also adapts the apparatus for use on animals other than man.

All pressure-volume changes occurring during the feeding period are automatically recorded on the polygraph tape.

Interval Timer. A special interval timer was designed and constructed which permitted of intervals of 1, 2, 4, 5, 10, and 20 seconds. It also made possible a total of 1,048,575 different pattern arrangements. Whether regular intervals or pattern arrangements were used, a special magnetic pen recorded the arrangement on the polygraph tape. Tumble switches made the setting up of any desired interval or pattern a very simple matter. The unit was also so devised that it could be set back to zero very readily in the event that pattern periodicities were being studied. All time intervals were derived from the 60-cycle, 1800 r.p.m., type S.A.S., 1/100 horsepower synchronous motor which powered the polygraph. Figure 7 shows the wiring circuit for the polygraph and the interval timer.

Calibration of the Apparatus. The calibration of the apparatus is described in the section on experimental technique.

Research Room. The room in which the present investigation was conducted is located on the fourth floor of the University Hospital in a position between the negro and white nurseries. Originally designed for use as a ward in the obstetrical division, it is of generous proportions, being 25 x 16 feet in size and well lighted and ventilated.

FIGURE 5

Stop-cock Manifold Connecting Right-hand Side of Manometer System with Polygraph Recorder

This unit is labelled *B* and shown functionally related to the complete unit in Figure 2.

1. One-way stop-cock serving as air inlet when auxiliary manometers are used to reduce amplitude.

2. Three-way parallel stop-cock. Upper outlet to air; lower bent outlet to polygraph; middle outlet to manometers. This stop-cock is supplementary to the four separate stop-cocks on the manometers and permits of their operation as a unit.

3. Three-way parallel stop-cock. Upper outlet to stop-cock *2*, this figure; lower outlet to stop-cock *1*, this figure; middle outlet to No. 3 burette manometer tube calibrated for cubic centimeters.

4, *5*, and *6*. Three-way parallel stop-cocks performing same function as *3*, except that they are connected to manometers *4*, *5*, *6*, respectively (Figure 4).

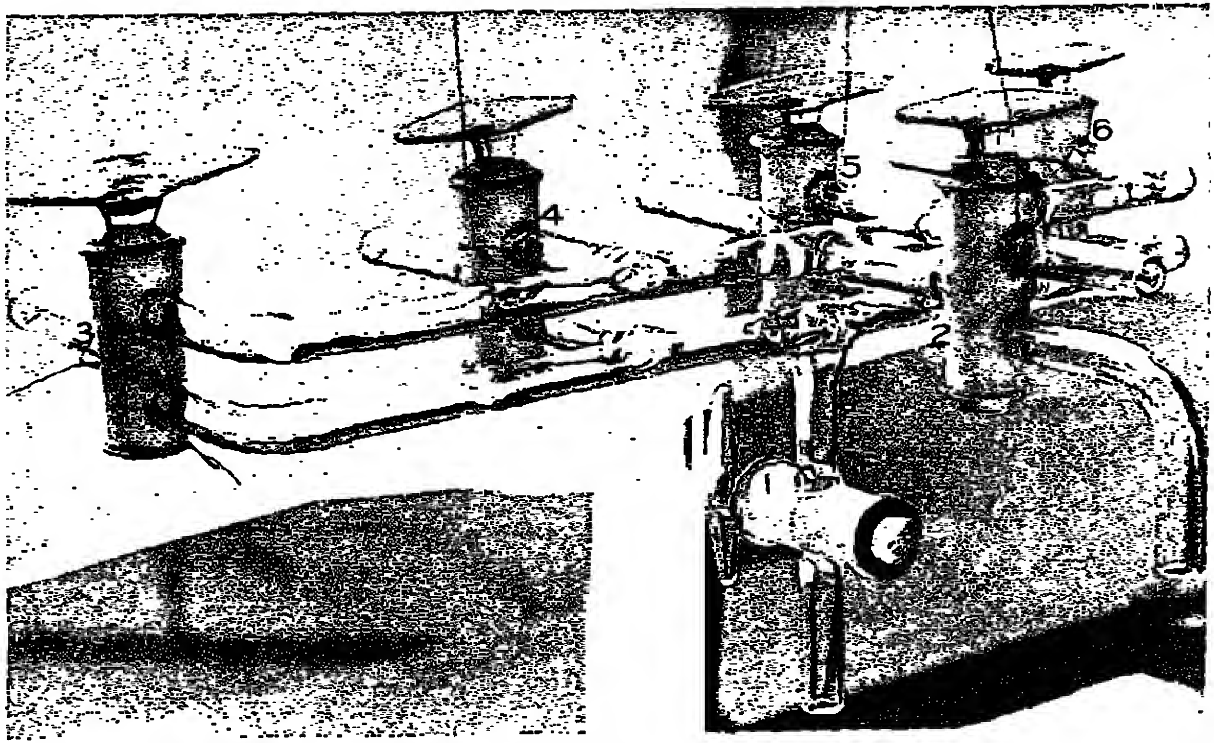


FIGURE 5

FIGURE 6

Special Feeding Bottle

This is labelled *A* and shown functionally connected in Figure 2.

1. Nipple.
2. Outlet for thermometer.
3. Sealed-in glass partition between air and food compartments.
4. Opening in partition *3*, this figure.
5. Air compartment.
6. One-way stop-cock connection to recording unit.

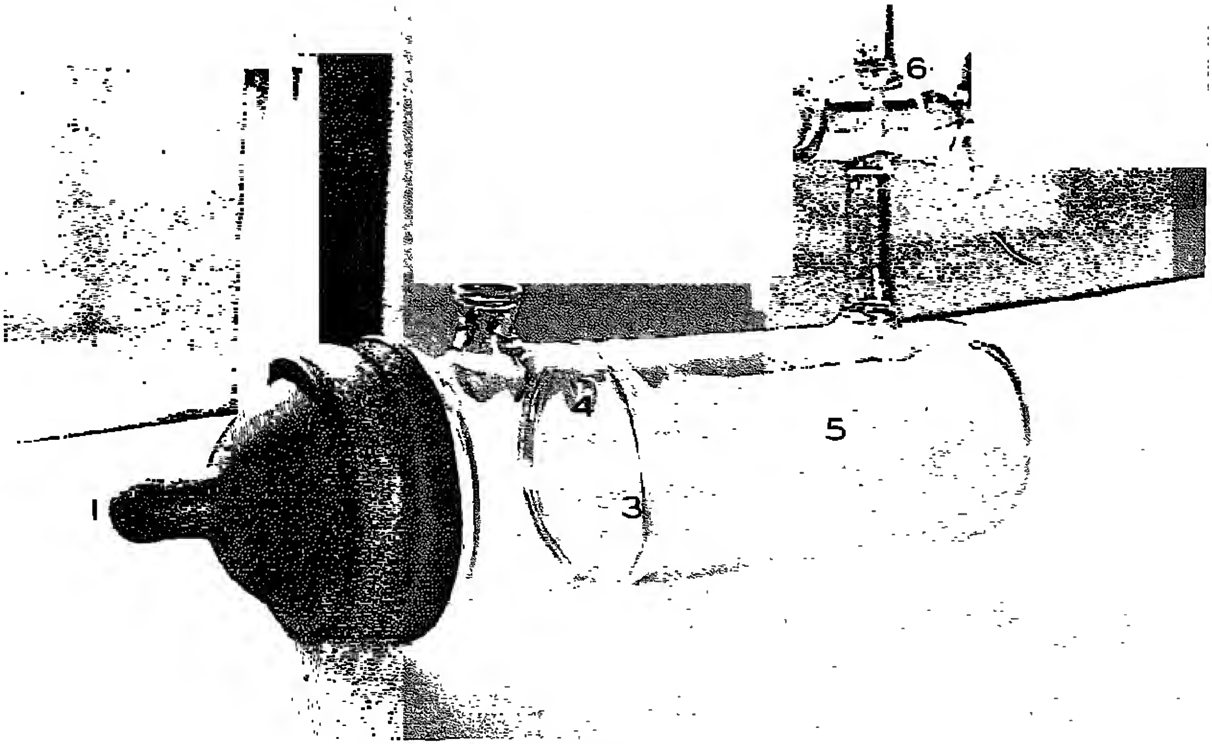


FIGURE 6

FIGURE 7

The figure facing this page shows the functional relationship between the previously described synchronous motor which powered the polygraph and the 20-point magnetic stepper which furnished the time intervals and pattern arrangements used in these experiments. The connections with the recording pens of the polygraph, the experimenter's stimulus keys, and the tumble switches which governed the time patterns, also appear. A reducing unit which lowered the motor-originated impulses from 30 to 1 per second is not shown.

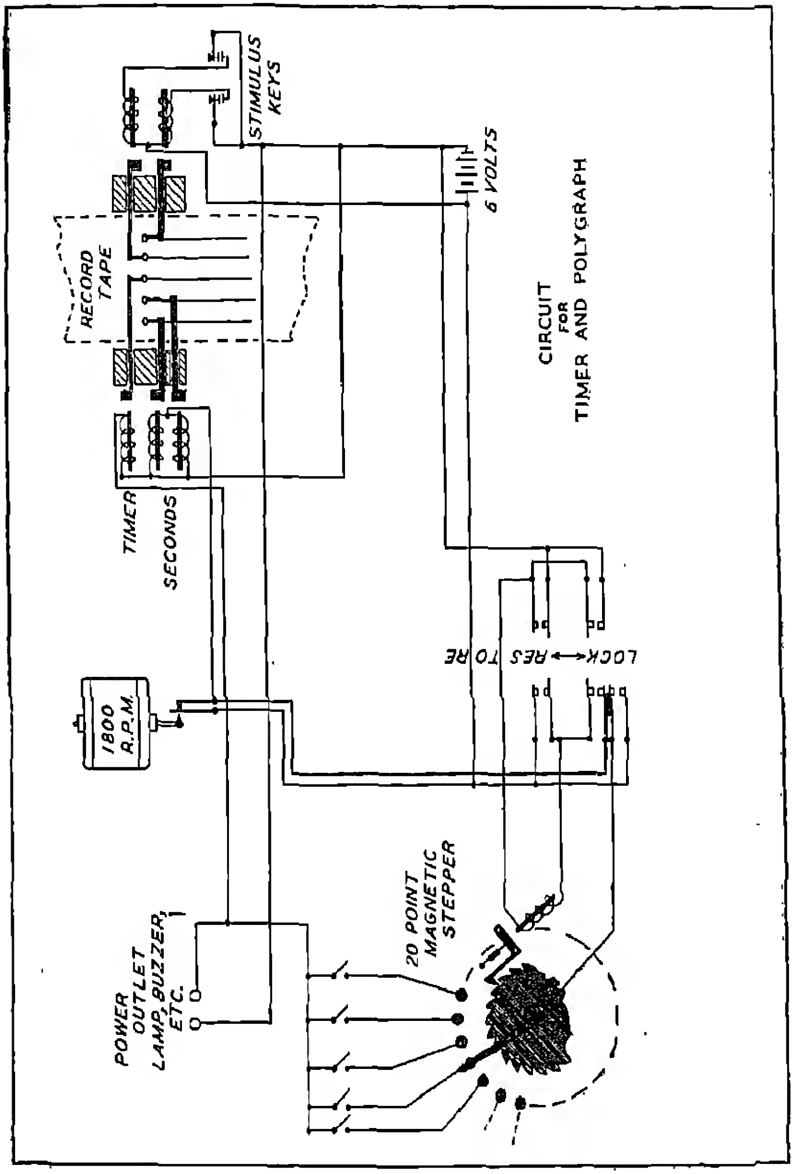

STIMULUS KEYS
6 VOLTS
RECORD TAPE
CIRCUIT FOR TIMER AND POLYGRAPH
TIMER
SECONDS
LOCK ↔ RES TO RE
1800 R.P.M.
20 POINT MAGNETIC STEPPER
POWER OUTLET LAMP, BUZZER, ETC.

FIGURE 8

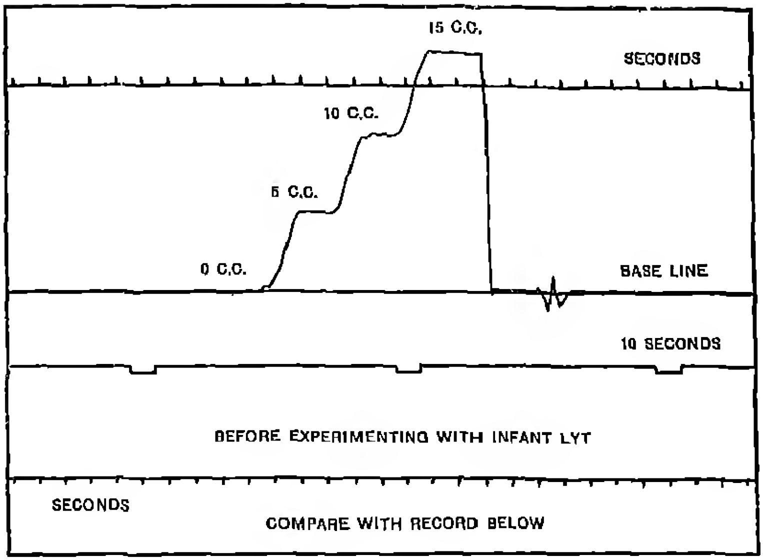
CALIBRATION OF THE APPARATUS

The records facing this page show specimens of the calibrations which were run before and after each feeding of all infants. A 50-cc. Luer syringe was used to draw the water in the manometer system to successive pressure levels of 5, 10, and 15 centimeters. Since the burettes from which the manometers were made were calibrated in cubic centimeters, the manometer readings also include the factor of volume. This has been indicated by the notation *c.c.* on the calibration records. All pressure readings refer to heights in centimeters of water (not mercury). Actually the pressure is negative (vacuum). Comparison of the two calibrations reveals at a glance any functional change in the apparatus. Sixteen of these calibrations were run daily. In all there were 852 such calibrations.

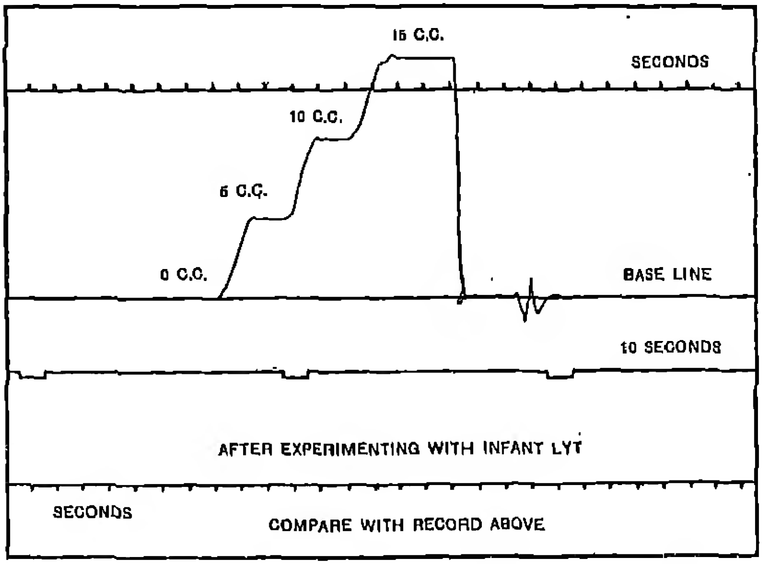
Weekly calibrations involving levels of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18 cc. were also run. Forty-five minutes were consumed in this calibration. This period was nine times the usual 5-minute period used in continuous feedings and 2700 times greater than the 10-second feeding interval used in the temperature and taste experiments. Levels 5, 10, and 15 were compared with the corresponding levels of the daily calibrations.

A second type of weekly calibration consisted in drawing the water in the manometric system to a given level and then turning off one of the terminal stop-cocks and leaving the apparatus in this condition overnight.

The three calibrations described above served to check on the consistency of the apparatus and also checked on leaks in the system. Furthermore, they made it possible to read pressure-volumes directly from the recorded curves.



RECORD 1

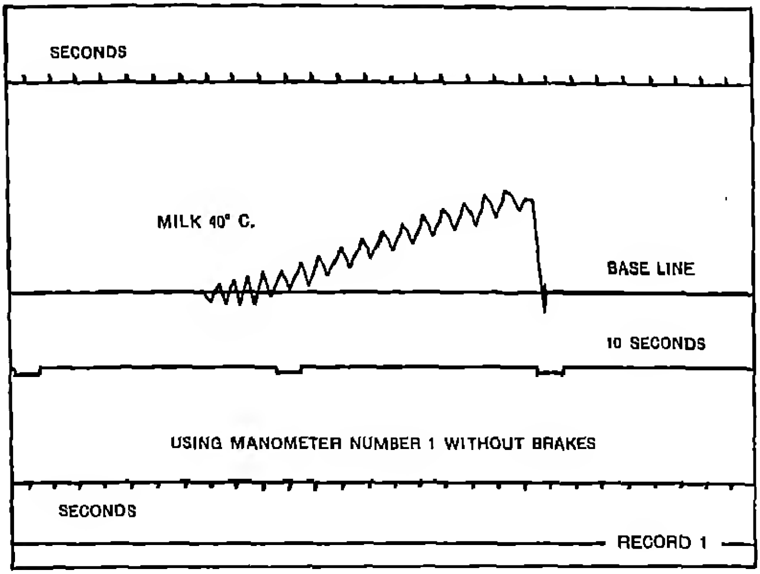


RECORD 2

FIGURE 9

Calibration of the Apparatus

As described in the section on apparatus, proper manipulation of the stop-cocks governing the manometer tubes permits of 2080 different amplitudes of record for a constant output. This flexibility makes it possible to secure just the right degree of amplitude for each infant. The records facing this page show the difference in the appearance of the sucking curves as different settings of the apparatus are used. The curve in Record 1 was obtained by using manometer No. I without any brakes. The curve in Record 2 was obtained while using manometer No. I and all brakes. It will be noticed that there is a difference in the amplitude of the individual sucks, those in Record 2 being much less. Also the steepness of curve is much less in Record 2. The setting used in Record 1 is suitable for short feeding intervals, while the setting used in Record 2 is better for long-continued sucking. Determination of optimum settings for each infant used was part of the experimental routine.


SECONDS
MILK 40° C.
BASE LINE
10 SECONDS
USING MANOMETER NUMBER 1 WITHOUT BRAKES
SECONDS
RECORD 1

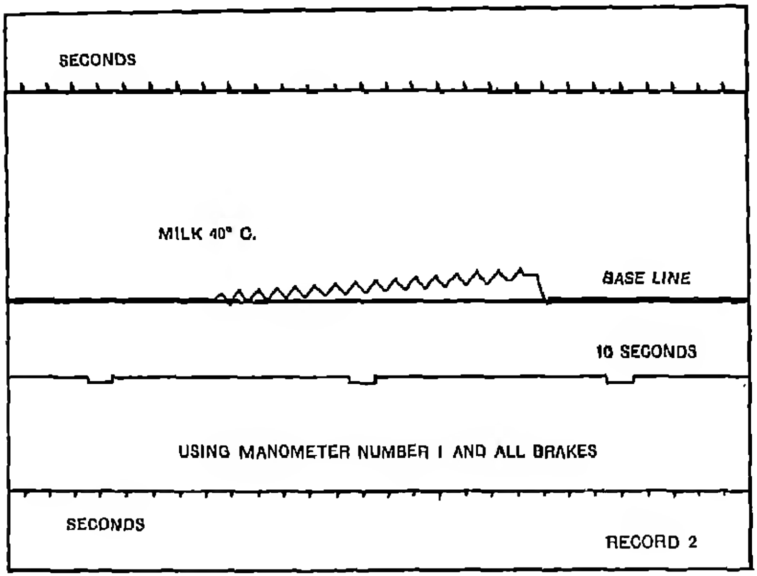

SECONDS
MILK 40° C.
BASE LINE
10 SECONDS
USING MANOMETER NUMBER I AND ALL BRAKES
SECONDS
RECORD 2

FIGURE 10

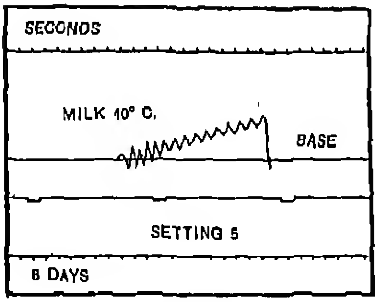
Calibration of Nipples

The nipples used were calibrated both by instrument and by comparison of actual sucking curves. In calibrating the nipples by instrument the water in the manometric system was raised to a pressure level of 40 cc. by means of a 50-cc. Luer syringe. This pressure was then released and the time necessary for it to reach zero, by forcing its way through the nipple attached to the nursing bottle, was recorded. Nipples with equal time records were then paired. These pairs of nipples were then further checked by comparing actual sucking curves of the infants.

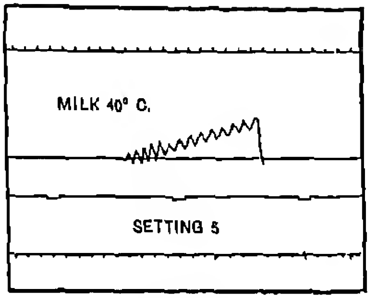
Figure 10 shows the differences in appearance of the sucking curves when nipples with varying sized outlets are used. Curves I and II show the results from two different nipples testing 5 (large outlet). Curves III and IV show the results from two different nipples testing 12 (medium outlet). Curves V and VI show the sort of record secured when two different nipples testing 20 (smallest outlet) were used. The values 5, 12, and 20 are arbitrary units derived from the time in seconds, volume, and height of manometer as given above.

All curves in Figure 10 were obtained from the same baby on the same day. The controls are not shown but were identical. It will be noted that two different curves with equal-testing nipples give virtually identical results, while at the same time curves for nipples testing 5, 12, and 20 are distinctly different. Frequently as high as 100 nipples would be tested before a suitable pair was obtained. The nipple used on the control mixture at one feeding was used on the experimental mixture at the next feeding and vice versa.

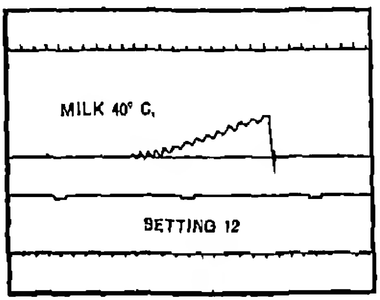
All rubber connections were of ¼-inch pure gum tubing and were changed every two weeks. The pens used were cleaned and put away after each feeding period. The apparatus was kept in a dust-proof cover between experimental periods.



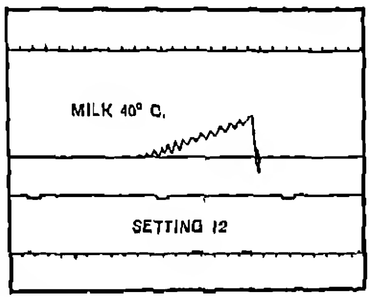
RECORD 1



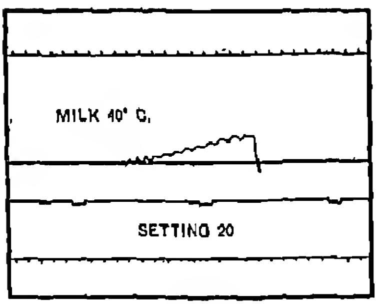
RECORD 2



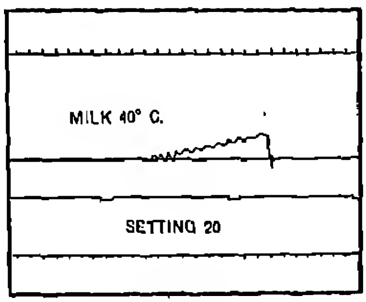
RECORD 3



RECORD 4



RECORD 5



RECORD 6

The Period of the Investigation. This research was divided into two main periods, a preliminary exploratory investigation extending from March 18th to April 30th, and the investigation proper, extending from June 17th to July 12th. In the preliminary research three feeding periods (9:30 A.M., 6:30 P.M., and 9:30 P.M.) were used, while in the main investigation four feeding periods (9:30 A.M., 3:30 P.M., 6:30 P.M., and 9:30 P.M.) were used.

The preliminary investigation was exploratory in nature and devoted to testing the scope and usefulness of the new apparatus and technique. Optimum settings of the apparatus and the best speed for the polygraph tape were ascertained. The nature of the feeding reaction was studied. The sucking curve was analyzed. The location of the swallows on the curve was determined by auscultating with a stethoscope over the esophagus. Different durations of control and experimental periods were compared, and a 10-second duration was finally decided upon. Preliminary taste and temperature experiments were made. The method for calibrating the nipples and apparatus was perfected and the experimental routine developed. At the end of the preliminary investigation the records to date were carefully analyzed and the program for the main investigation formulated.

In the main investigation the tentative conclusions from the preliminary investigation were checked, the experimental procedure perfected, and the main experiments on temperature and taste completed.

Sanitary Precautions. The experimenter and his assistants wore sterilized hospital gowns which were changed every other day and oftener if necessary. The hands of the individuals engaging in the experimental work were washed before and after handling each infant. All apparatus was sterilized after the feeding of each infant and kept between sterile towels between experimental periods.

The salt, glucose, sterile water, distilled water, and acid used in the taste experiments were secured from Surgery. A 6-per-cent glucose solution was used. This was heated to 240° F. for ten minutes on two separate occasions, a 24-hour period intervening between heatings. The solution was then sealed in a sterile bottle. A .9-per-cent salt solution (physiological saline) was used. This was prepared by being maintained at a temperature of 259° F. for a 20-minute period and was then sealed in a sterile flask. In the dilution experiments, distilled water, also obtained from Surgery, was used.

The formulae used were prepared by the maternity nurses under the supervision of Miss Ickes or Miss Evans. These contained the following ingredients:

Formula number 1:

Milk	7 oz.
Barley water	14 oz.
Karo (brown)	16 oz.

Formula number 2:

Milk	9 oz.
Barley water	12 oz.
Karo (brown)	32 oz.

Formula number 3:

Milk	10 oz.
Barley water	11 oz.
Karo (brown)	40 oz.

The New Experimental Procedure. The technique developed in this research consisted in comparing sucking reactions to various experimental stimuli with a control sucking reaction, all curves being objectively recorded. Milk at a temperature of 40°C. was used as a control. This was administered for 10 seconds. After a wait of 20 seconds the experimental mixture (sterile water, glucose 6 per cent, .900-per-cent salt, .450-per-cent salt, .300-per-cent salt, .225-per-cent salt, or milk at temperatures above or below 40°C.) was administered for 10 seconds. Then after 20 seconds the control was readministered. This procedure was continued until at least six controls had been given. The controls being identical, any deviation from the control curve by the experimental curve was interpreted as a differential reaction. These differential reactions were not of an all-or-none character but proved to be gradual deviations from the control curves, becoming more marked as the temperature was raised or lowered as compared with the control and as the percentage of salt solution was increased.

The order of presentation of both experimental stimuli and controls was continually varied to avoid space-time errors and as a check on positive and negative adaptation.

The Experimental Procedure Proper. The routine experimental procedure in time order was as follows:

1. The infant was observed for 5 minutes and then brought from the nursery to the research room.
2. A record was made of the name of the infant, the date, the time of day, the condition of the infant, the behavior of the infant, and the temperature and humidity.
3. The amount of milk or formula to be used as a control was measured and placed in the nursing bottle.
4. The amount of salt or other experimental mixture was measured and placed in a second nursing bottle.
5. The desired temperature for both control and experimental mixture was secured. An electric heater was used to warm the feeding mixture and an ice bath to cool it to any desired temperature.
6. The infant's basinet was tilted to an angle of 15 degrees.
7. The polygraph was started and the recorder calibrated.
8. The infant was given the control (milk at a temperature of 40° C.) for 10 seconds.
9. The temperature was retaken as soon as the 10-second period was completed.
10. The amount remaining was ascertained.
11. The salt or other experimental mixture was then given to the baby for 10 seconds.
12. The temperature of the salt or other experimental mixture was then redetermined as soon as the 10-second administration was over.

13. The amount remaining was ascertained.

14. The infant was then given the control again at the original temperature for 10 seconds.

15. Steps 9 and 10 were then repeated and the whole process repeated at least three times.

The order of presentation was continually varied to eliminate space-time errors, and no results in which less than six controls appeared were ever used.

The Experimenters. It was the duty of one experimenter to get the milk, salt, etc., to be used, to measure the amounts before and after each administration to the infant, to raise or lower the feeding mixture and the experimental mixture to the desired temperatures, and to wash and sterilize the bottles and nipples used.

It was the duty of the second experimenter to observe the infant for 15 minutes before experimentation began, to change its diaper if necessary, to bring the baby from the nursery to the research room, to feed the baby, to observe and report significant reactions, to observe the infant for 15 minutes following completion of the feeding period and to return it to the nursery.

It was the duty of the third experimenter to keep the apparatus in first-class mechanical condition, to calibrate the nipples and recorder, and to start and to stop the apparatus.

The Infant. The infant was observed for at least 15 minutes before and for at least 15 minutes after each feeding period. The physiological condition—awake, asleep, dry, wet, soiled, crying, quiet—given in con-

nection with each record refers to his condition when first observed and not to his condition during the experiment. This technique was adopted because the babies were always changed before being brought into the research room if wet or soiled. Unless otherwise indicated, they were also awakened for their feeding, because the preliminary investigation had revealed that an awake, alert baby was a better subject than a baby which was asleep. A record was made of the name, date, time of day, condition, behavior, temperature, and humidity for each infant at each feeding. The complete hospital data for each infant used were also secured and studied.

Two infants were used at each experimental period, and the same infants were used at each feeding period as long as they remained in the hospital. The total program for each infant was as follows:

1. Continuous water feeding curve on day of birth secured.

2. Milk or formula feeding continued until continuous sucking occurred for at least 30 seconds.

3. Tested for presence of nystagmus on day of birth.

4. Sterile water record compared with milk record.

5. Reactions to glucose compared with reaction to milk.

6. Reactions to .900-, .450-, .300-, and .225-per-cent salt solutions compared with control reaction.

7. Reactions to milk at temperatures above 48° C. and below 25° C. compared with control reactions.

8. Optimum setting of recorder and best nipples for each infant determined.

9. Continuous air sucking records obtained.

10. Intermittent air sucking records secured.

11. Effect on sucking of pinching toe, pulling hair, and sudden dropping studied.

12. Moro reflex tested.

III

Data and Results

The results of the present investigation are presented in the form of photographic reproductions of the original unretouched records. Opposite each illustration there is a page explaining the experiment in question.

TABLE 1

Sex and Race Distribution of Subjects

	White	Negro	Total
Male	6	3	9
Female	2	6	8
Total	8	9	17

TABLE 2

Summary of Experiments

Situation	Frequency
First water feeding	10
Second water feeding	10
First milk feeding	12
Continuous feeding	100
Calibration of nipples	100
Sterile water	82
Acid	20
6% glucose	82
.900 salt and 6% glucose	52
.900 salt solution	312
.450 salt solution	174
.300 salt solution	162
.225 salt solution	170
.200 salt solution	67
Pinched toe	165
Pulled hair	115
Dropped 4 inches	20
Nose held	24
Sucking on air	604
Temperature	450
Total	2731

FIGURE 11

Types of Differential Reaction

The next three figures show various types of differential reactions. On the page facing this one are given six examples of Type 1. The characteristic of this type is that sucking occurs for a few seconds, then there is a short break after which sucking is resumed. This reaction is accompanied by pressure increase in specimens 1, 2, 3, and 4.

Record 1. Infant Als—female, negro—9:30 A.M.—wet, crying—4 days old.

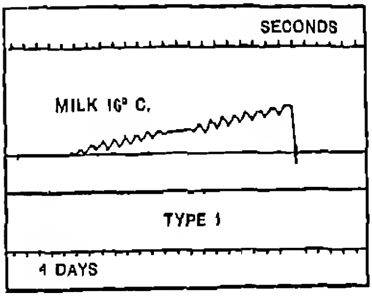
Record 2. Infant Als—female, negro—7:00 P.M.—wet, crying—9 days old.

Record 3. Infant Hef—female, white—3:30 P.M.—dry, asleep—9 days old—humidity 90-74.

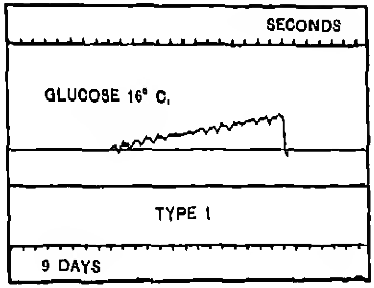
Record 4. Infant Lyn—male, white—4:10 P.M.—dry, crying—8 days old—humidity 87-75.

Record 5. Infant Can—female, negro—6:30 P.M.—dry, asleep—6 days old.

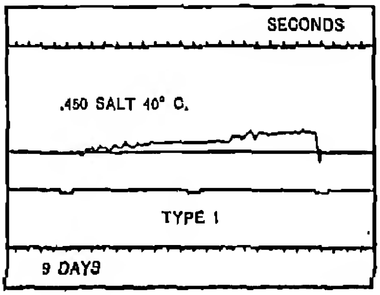
Record 6. Infant Can—female, negro—9:30 A.M.—dry, awake—5 days old.



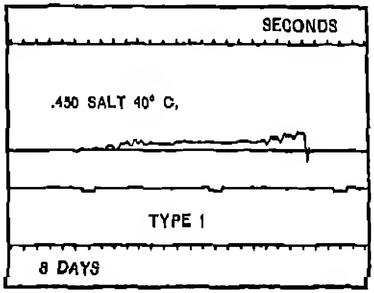
RECORD 1



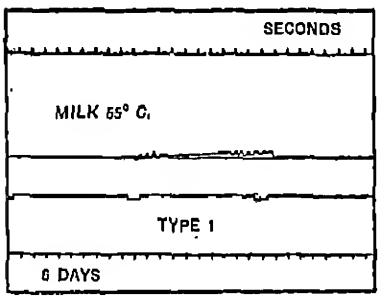
RECORD 2



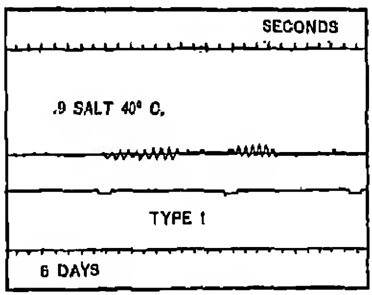
RECORD 3



RECORD 4



RECORD 5



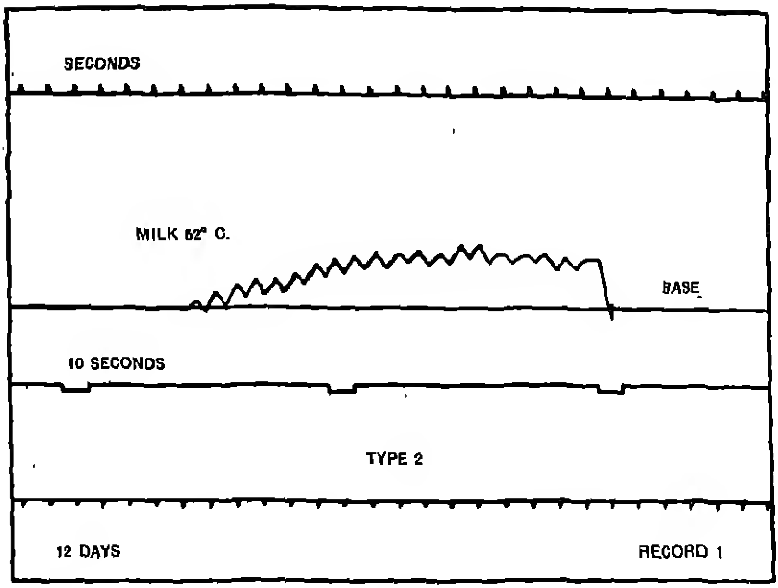
RECORD 6

FIGURE 12

Types of Differential Reaction

Record 1 facing this page illustrates Type 2. The chief characteristic of this type of differential reaction is that the increase in pressure is not uniform. Sucking movements continue throughout, but the pressure remains constant or drops slightly. (Infant Fra—female, negro—9:30 P.M.—wet, crying—12 days old—humidity 84-73.)

Record 2 facing this page illustrates Type 3. In this type there is initial sucking, then a break or decrease in amplitude of the individual sucks, then a few sucks followed by another break and finally another period of sucking. (Infant Hef—female, white—6:30 P.M.—soiled, awake, and quiet—5 days old.)


SECONDS
MILK 52° C.
BASE
10 SECONDS
TYPE 2
12 DAYS
RECORD 1

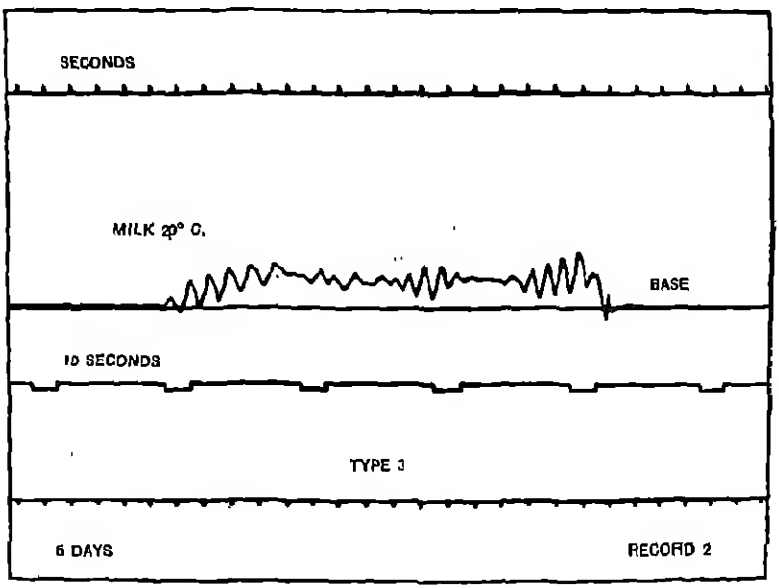

SECONDS
MILK 20° C.
BASE
10 SECONDS
TYPE 3
6 DAYS
RECORD 2

FIGURE 13

Types of Differential Reaction

Records 1, 2, 3, and 4 facing this page are examples of Type 4. In this type, which was found most frequently in these experiments, there is pronounced sucking for an interval of from 3 to 12 seconds. This type of reaction is usually found at the temperature thresholds.

Record 1. Infant Wis—female, negro—9.30 P.M.—dry, awake—6 days old.

Record 2. Infant Wis—male, negro—6:30 P.M.—wet, crying—10 days old.

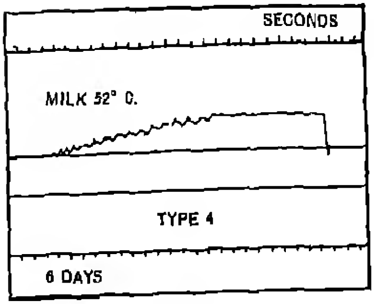
Record 3. Infant Hef—female, white—3:30 P.M.—dry, asleep—9 days old.

Record 4. Infant Hef—female, white—6:30 P.M.—soiled, awake—7 days old—humidity 87-73.

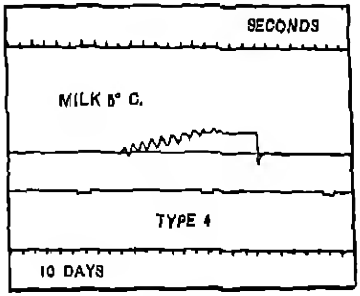
Records 5 and 6 illustrate Type 5. In Type 5 there is initial sucking followed by coughing for from 1 to 4 seconds, after which sucking movements reappear.

Record 5. Infant Fra—female, negro—9:30 P.M.—soiled, asleep—6 days old—humidity 86-74.

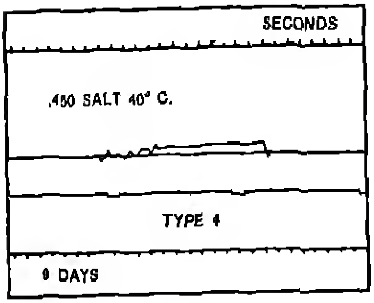
Record 6. Infant Swi—male, white—6:30 P.M.—wet, crying—5 days old—humidity 90-76.



RECORD 1



RECORD 2



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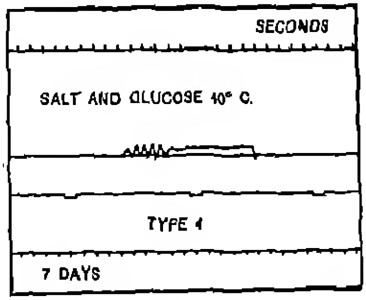

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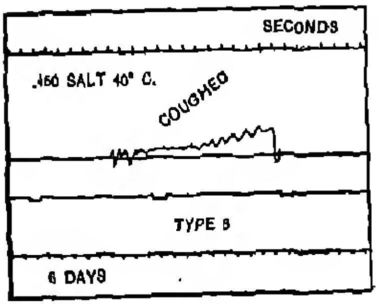
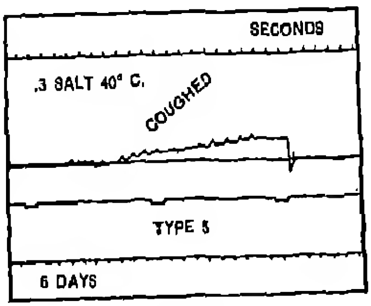


RECORD 5



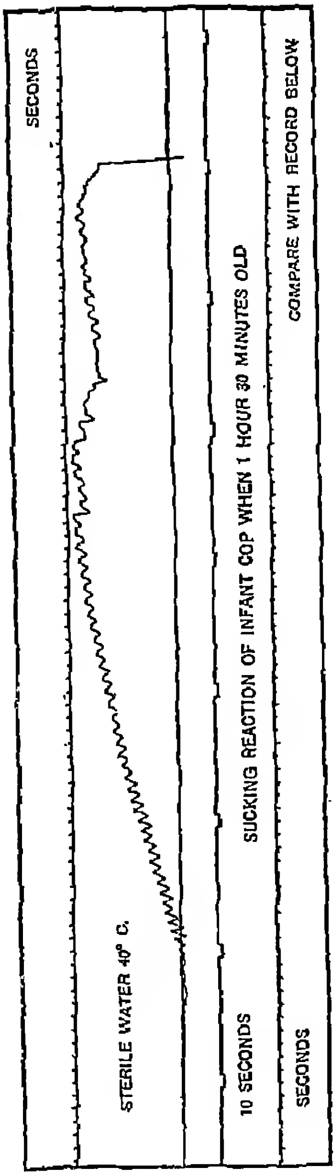
RECORD 6

FIGURE 14

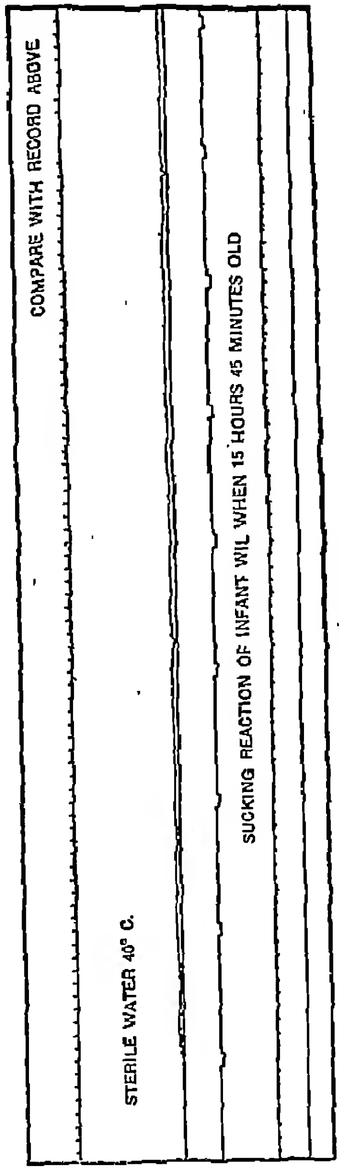
Individual Differences in Sucking Reactions

Record 1 facing this page shows excellent sucking on the part of an infant 1 hour and 30 minutes old. This was the best record secured at such an early age. (Infant Cop—male, white—3:45 P.M. —wet, crying, very active—humidity 86-72.)

Record 2 shows virtual absence of the sucking response in an infant 15 hours and 45 minutes old. (Infant Wil—male, white—9:30 A.M.—dry, awake, quiet—humidity 82-72.)



RECORD 1



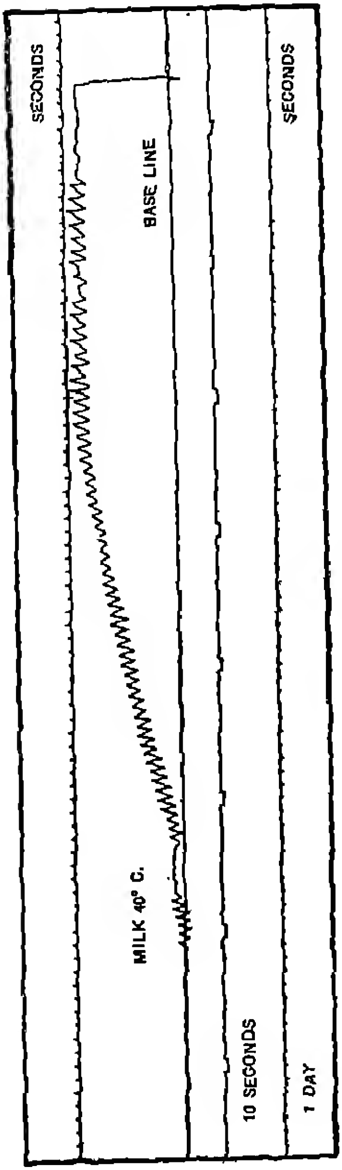
RECORD 2

FIGURE 15

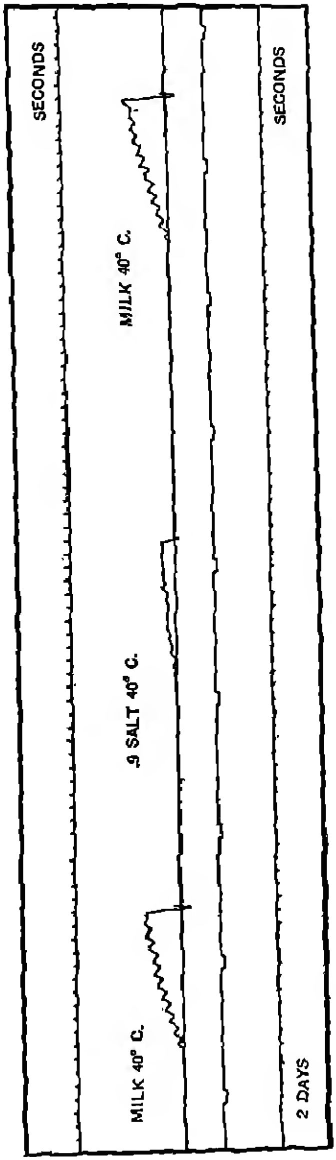
First Milk Feeding and Early Differential Reactions to Salt

Record 1 on the page facing this one shows excellent continued sucking on the part of an infant 1 day old. This was the first milk feeding for this particular infant. (Infant Cop—male, white—3:30 P.M.—dry, awake—humidity 84-68.)

Record 2. (Infant Cop—male, white—9:30 A.M.—dry, asleep—2 days old—humidity 78-66.) Usually experiments on differential reactions were not begun until the third day, but this record shows a definite differential reaction to .900 salt using milk at a temperature of 40° C. as a control.



RECORD 1



RECORD 2

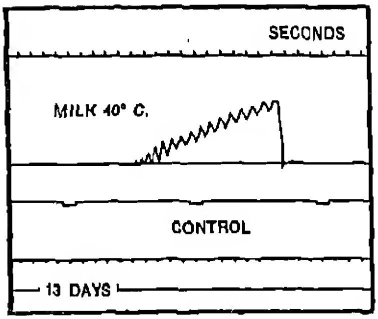
FIGURE 16

TEMPERATURE—UPPER THRESHOLD

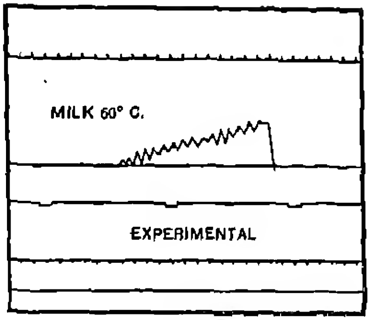
The page facing this one shows the results of the experiment in which the upper temperature threshold for infant Fra was ascertained. (Infant Fra—female, negro—6:45 P.M.—dry, awake—13 days old—humidity 86-71.) (Only two controls are shown, though six were given.) Record 1 shows the original control. Record 2 shows a slight break in the sucking curve at 50° C. Record 3 shows a more pronounced differential reaction at 53° C. Record 4 shows a very pronounced differential reaction at 55° C., and 5 shows that the infant began crying at 57° C. Record 6 shows the final control.

These curves show:

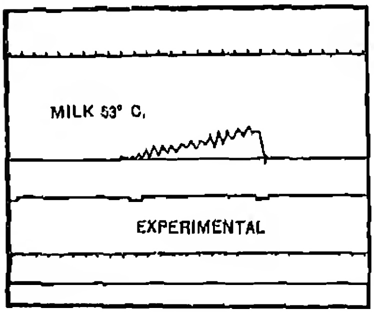
1. That milk at the temperatures of 40, 50, 53, 55 and 57° C. was administered.
2. That differential reactions were secured to milk of 50, 53, 55, and 57° C.
3. That the upper threshold was 50° C.
4. That when high temperatures were used as stimuli, the differential reaction became greater and greater as the temperature became higher and higher.



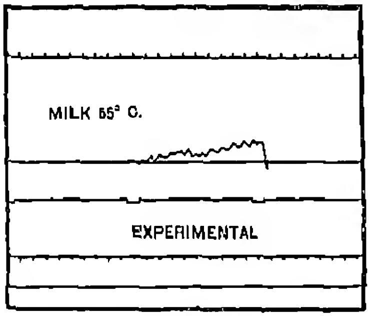
RECORD 1



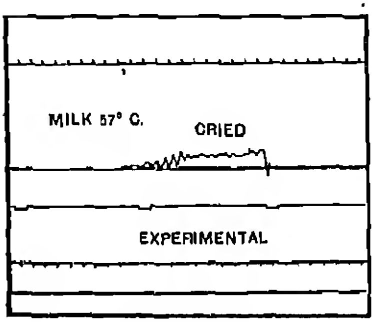
RECORD 2



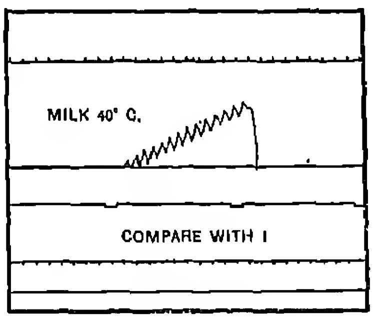
RECORD 3



RECORD 4



RECORD 5



RECORD 6

FIGURE 17

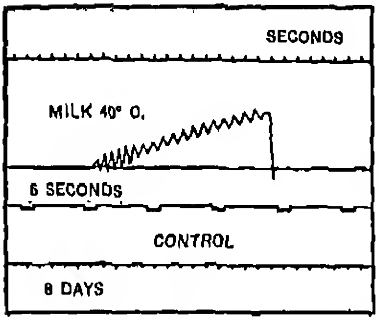
Temperature—Lower Threshold

The page facing this one shows the results of the experiment in which the lower temperature threshold for infant Cop was ascertained. (Infant Cop—male, white—3:30 P.M.—wet, awake—8 days old—humidity 84-66.) Only two controls are shown, though seven were given.

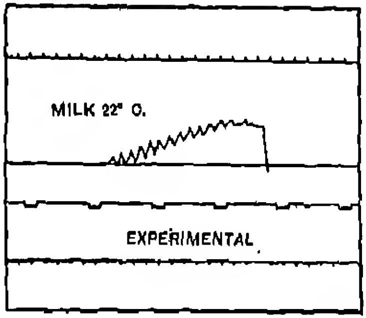
Record 1 shows the original control. Record 2 shows a slight differential reaction to milk at 22° C. Record 3 shows a more pronounced differential reaction at 20° C. Record 4 shows a still more marked differential reaction at 18° C. Record 5 shows that the most pronounced differential reaction occurred at 16° C. Record 6 shows the final control.

This experiment shows:

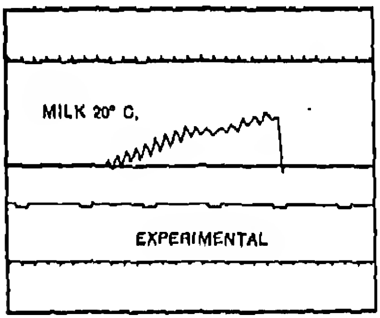
1. That milk at the temperatures of 40, 22, 20, 18, and 16° C. was administered.
2. That differential reactions were secured to milk of 22, 20, 18, and 16° C.
3. That the lower threshold was 22° C.
4. That when low temperatures were used as stimuli the differential reaction became greater and greater as the temperature became lower and lower.



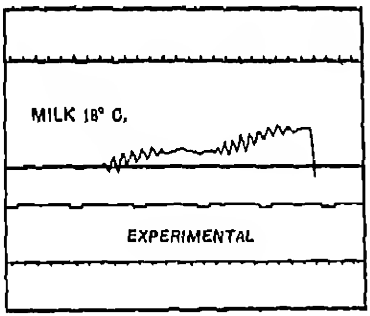
RECORD 1



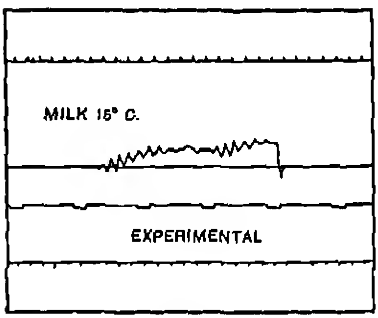
RECORD 2



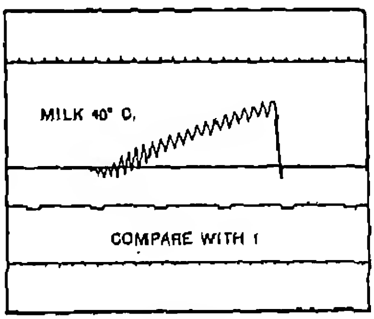
RECORD 3



RECORD 4



RECORD 5



RECORD 6

FIGURE 18

Temperature—Upper Threshold

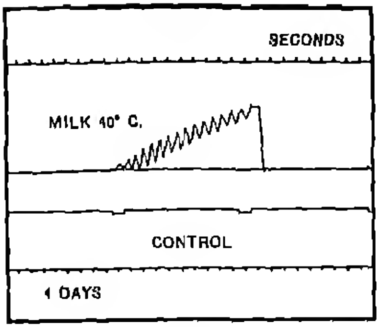
The page facing this one shows the results of the experiment in which the upper temperature threshold for milk was ascertained for infant Cop. (Infant Cop—male, white—6:30 P.M.—soiled, crying—4 days old—humidity 85-71.) Only two controls are shown, though seven were given.

Record 1 shows the original control using milk at 40° C. Record 2 shows a pronounced differential reaction to milk at 60° C. It will be noted that the infant began vigorous crying. Pronounced avoidance movements were also noted. Record 3 shows a marked differential reaction to milk at a temperature of 55° C. At this temperature whimpering occurred. Record 4 shows a slight differential reaction to milk at a temperature of 53° C. Record 5 shows that no differential reaction was made to milk at a temperature of 47° C. Record 6 is the final control.

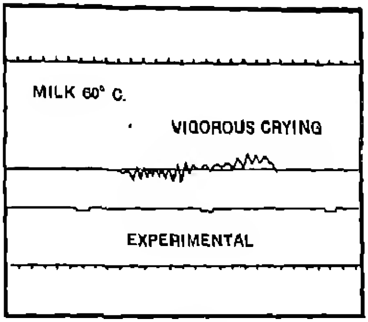
This experiment shows:

1. That milk at the temperatures of 40, 60, 55, 53, 47, and 40° C. was administered.
2. That differential reactions were secured to milk at the temperatures of 60, 55, and 53° C.
3. That the upper threshold was 53° C.
4. That no differential reaction was made to milk at a temperature of 47° C.
5. That when high temperatures were used as stimuli, the differential reaction became greater and greater as the temperature became higher and higher.

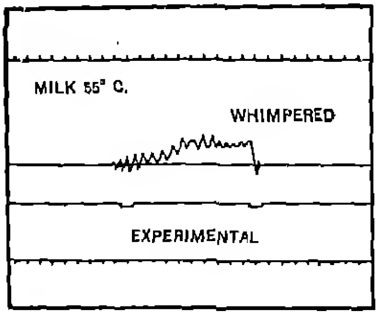
Note: Comparison of this figure with Figure 16 shows that reversing the order of presentation of stimuli does not interfere with obtaining the thresholds.



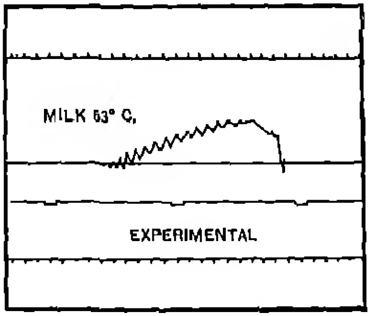
RECORD 1



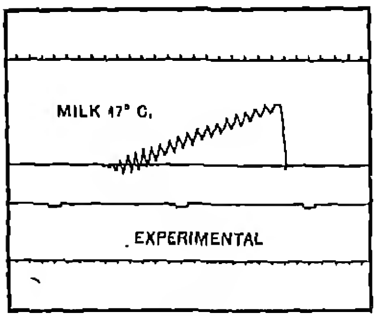
RECORD 2



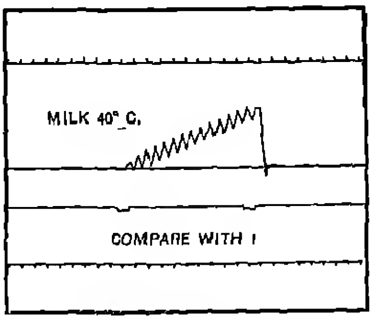
RECORD 3



RECORD 4



RECORD 5



RECORD 6

FIGURE 19

Temperature Thresholds

The page facing this one contains a portion of the record of the experiment in which the lower threshold for infant Cop and the upper threshold for infant Fra were obtained.

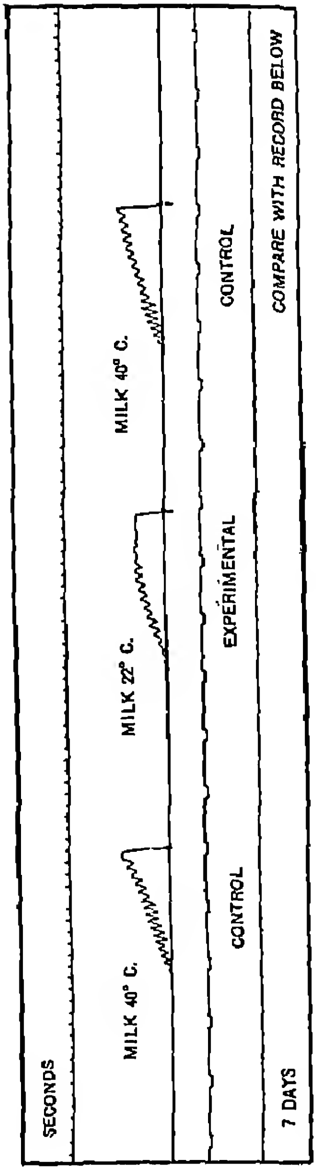
In Record 1 only two controls and one experimental temperature are shown, although actually eight controls were given as were also experimental temperatures of 23, 22, 20, and 19° C. (Infant Cop—male, white—9:30 A.M.—soiled, crying—7 days old—humidity 76-65.) This record shows:

1. That a differential reaction to milk at 22° C. was obtained.
2. That the lower temperature threshold was 22° C. (No differential reaction was secured at 23° C., and increasingly greater differential reactions were secured at 20° and 19° C.)

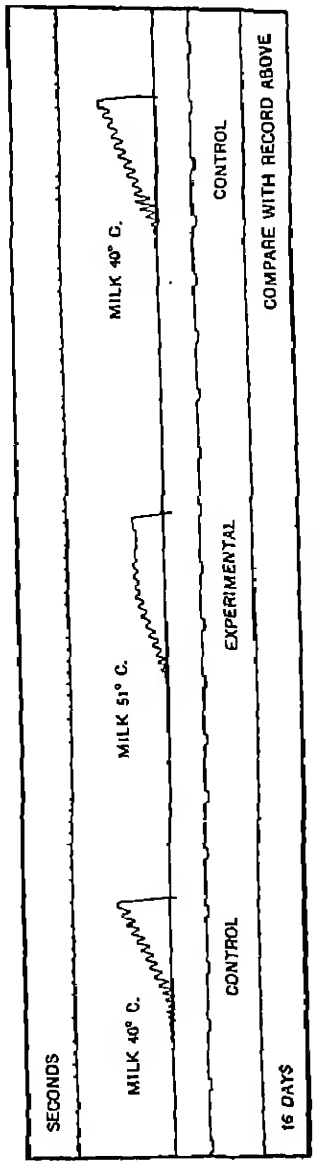
Record 2 shows only two controls and one experimental temperature, although actually seven controls were given, as were also experimental temperatures of 55, 53, 52, 51, and 49° C. (Infant Fra—female, negro—3:50 P.M.—dry, asleep—16 days old—humidity 84-66.) This record shows:

1. That a differential reaction to milk at 51° C. was given.
2. That the upper temperature threshold was 51° C. (No differential reaction was secured at 49°, and increasingly greater differential reactions at 52, 53, and 55° C.)

Note: Comparison of these results with those presented in Figures 17 and 16 shows that the lower temperature threshold for infant Cop at 7 days was identical with that at 8 days and that the upper theshold for infant Fra was 50° C. on the 13th day and 51° C. on the 16th day.



RECORD 1



RECORD 2

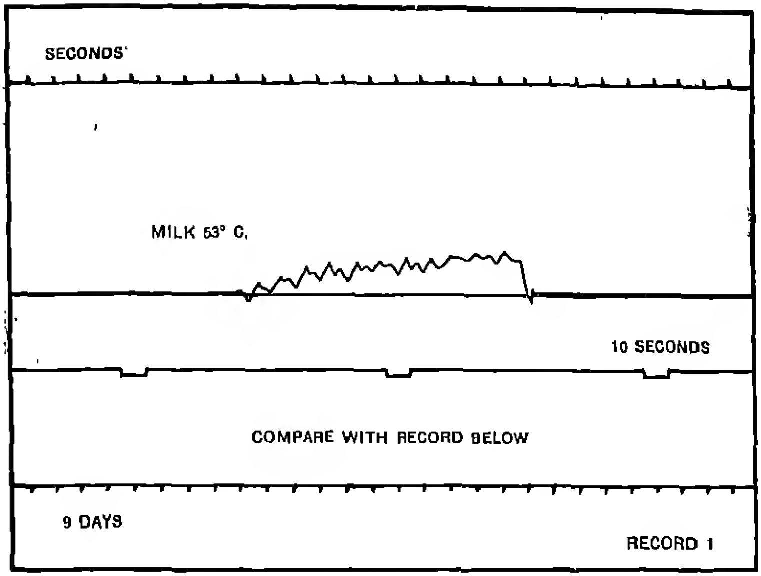
FIGURE 20

TEMPERATURE—COMPARISON OF UPPER AND LOWER THRESHOLDS

The sections of record facing this page are taken from the results of an experiment in which the differential reactions to milk at high and low temperatures for the same infant were compared. No controls are shown, though eight were given. Also, the experiment was repeated three times with identical results. (Infant Lyn—male, white—9:30 A.M.—wet, crying—9 days old—humidity 86-70.)

These records show:

1. That pronounced differential reactions were made to milk at temperatures of 53 and 17° C.
2. That the differential reaction to milk at 53° C. was virtually identical with that made to milk at a temperature of 17° C.


SECONDS
MILK 53° C.
10 SECONDS
COMPARE WITH RECORD BELOW
9 DAYS
RECORD 1

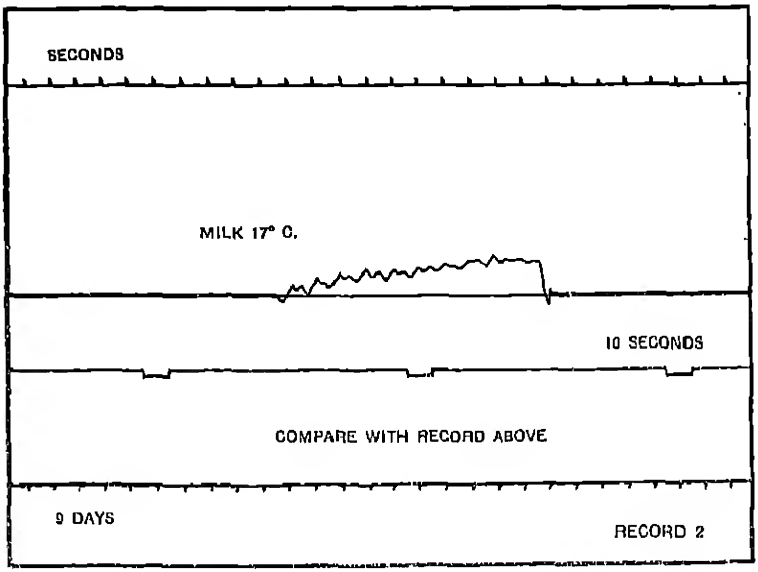

SECONDS
MILK 17° C.
10 SECONDS
COMPARE WITH RECORD ABOVE
9 DAYS
RECORD 2

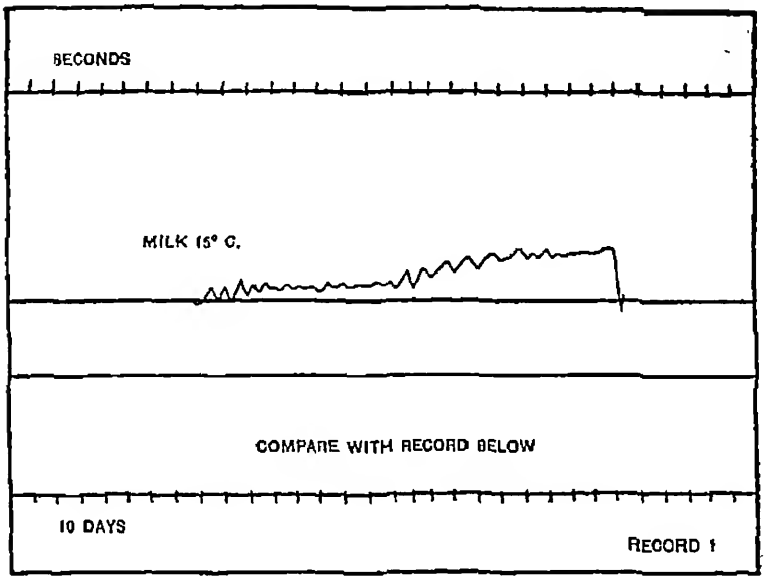
FIGURE 21

Comparison of Differential Reactions to Milk at High and Low Temperatures

The sections of record facing this page are taken from the results of an experiment in which the differential reactions to milk at high and low temperatures for the same infant were compared. No controls are shown, though seven were given and the experiment repeated three times with virutally identical results. (Infant All—female, negro—9:30 A.M.—dry, awake—10 days old.)

These records show:

1. That pronounced differential reactions were given to milk at temperatures of 15 and 57° C.
2. That the differential reaction to milk at a temperature of 15° C. was virtually the same as that made to milk at a temperature of 57° C.


SECONDS
MILK 15° C.
COMPARE WITH RECORD BELOW
10 DAYS
RECORD 1

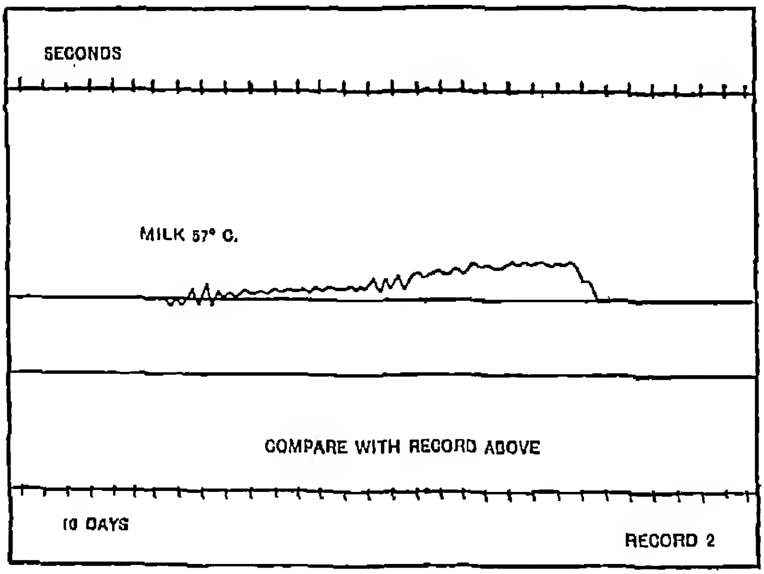

SECONDS
MILK 57° C.
COMPARE WITH RECORD ABOVE
10 DAYS
RECORD 2

FIGURE 22

Comparison of Differential Reactions to Milk at High and Low Temperatures

Records 1 and 2 facing this page show:

1. That pronounced differential reactions were given to milk at temperatures of 59 and 14° C.
2. That the differential reaction to milk at a temperature of 59° C. was virtually identical with that made to milk at a temperature of 14° C.

   (Infant Hef—female, white—6:30 P.M.—wet, asleep—9 days old—humidity 92-75.)

Records 3 and 4 facing this page show:

1. That definite differential reactions were made to milk at temperatures of 54 and 17° C.
2. That the differential reaction to milk at a temperature of 54° C. was virtually identical with that made to milk at a temperature of 17° C.

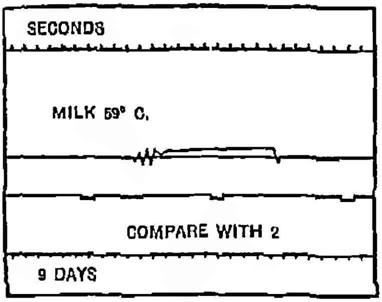
Note: Records 1, 2, 3, and 4 were made by the same infant and show:

1. That much more pronounced differential reactions were made to milk at temperatures of 59 and 14° C. than at 54 and 17° C.

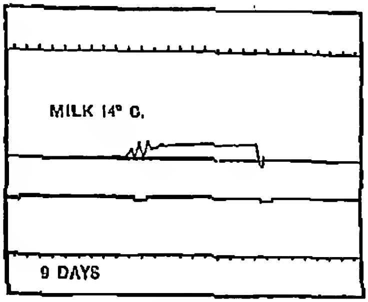
Records 5 and 6 facing this page show:

1. That pronounced differential reactions were made by infant Can to milk at temperatures of 55 and 18° C.
2. That the differential reaction made to milk at a temperature of 55° C. was virtually identical with that made at a temperature of 18° C.

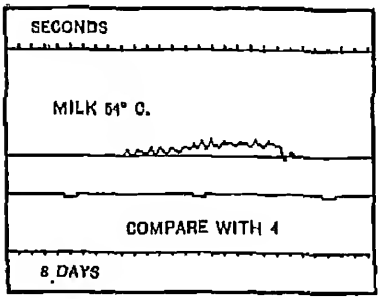
   (Infant Can—female, negro—9:30 A.M.—dry, awake—6 days old.)



RECORD 1



RECORD 2



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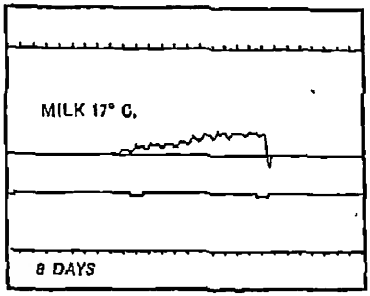

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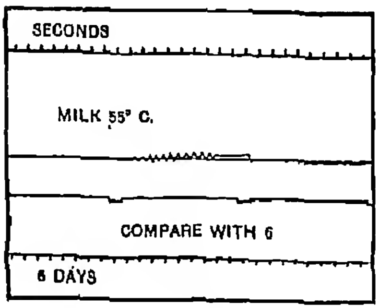
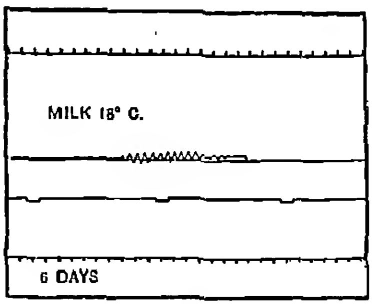


RECORD 5



RECORD 6

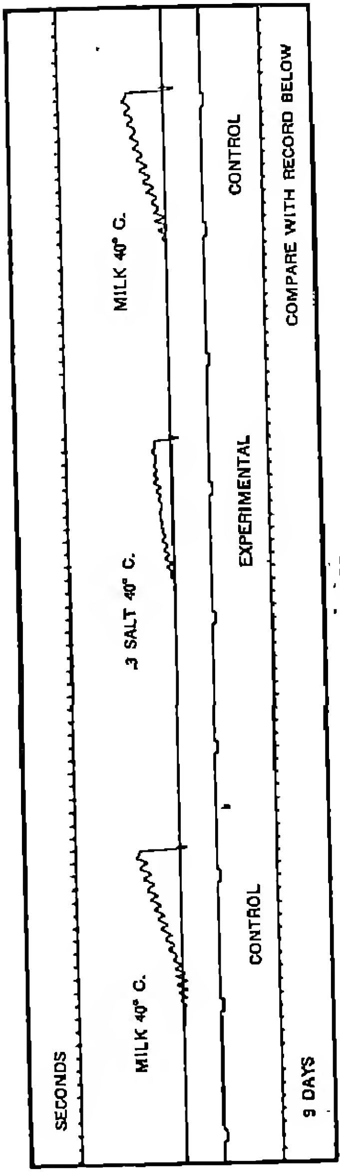
FIGURE 23

DIFFERENTIAL REACTIONS TO SALT SOLUTION

Records 1 and 2 facing this page are for the same infant, 2 being a direct continuation of 1, and show:

1. That milk at a temperature of 40° C. was administered, then .300 salt solution at 40° C., then milk at 40° C., then milk at 40°C. again, then .225 salt solution at 40° C., and finally milk at 40° C.
2. That no differential reaction was made to .225 salt solution at 40° C.
3. That a pronounced differential reaction to .300 salt solution at 40° C. was made.
4. That the threshold for salt dilution was .300 per cent.
5. That the infant reacted differentially to a difference in salt solution of .075 per cent.
6. That the differential reaction to salt solution was definitely greater as the percentage of salt in solution was increased.

(Infant Hef—female, white—9:30 P.M.—dry, asleep—9 days old—humidity 89-75.)


SECONDS
MILK 40° C.
.3 SALT 40° C.
MILK 40° C.
CONTROL
EXPERIMENTAL
CONTROL
COMPARE WITH RECORD BELOW
9 DAYS
RECORD 1

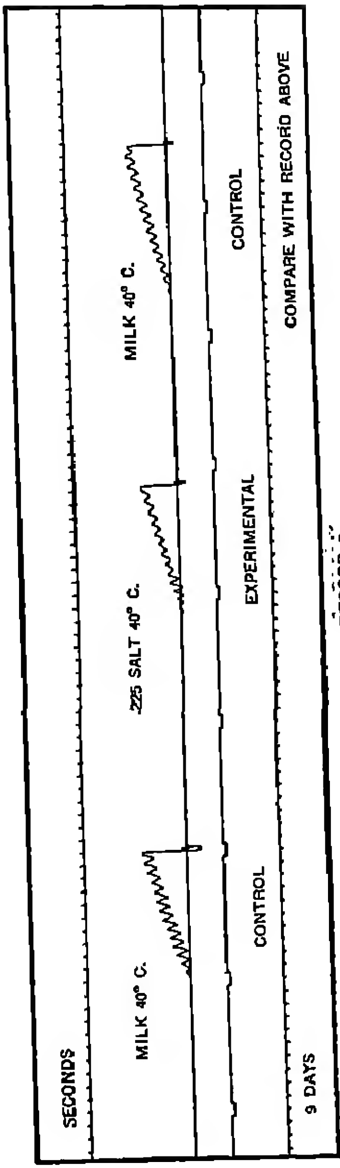

SECONDS
MILK 40° C.
.225 SALT 40° C.
MILK 40° C.
CONTROL
EXPERIMENTAL
CONTROL
COMPARE WITH RECORD ABOVE
9 DAYS
RECORD 2

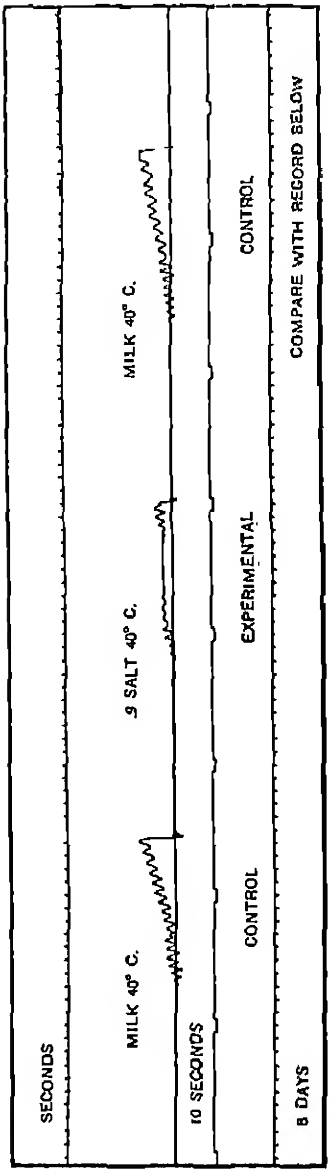
FIGURE 24

Differential Reactions to Salt Solution

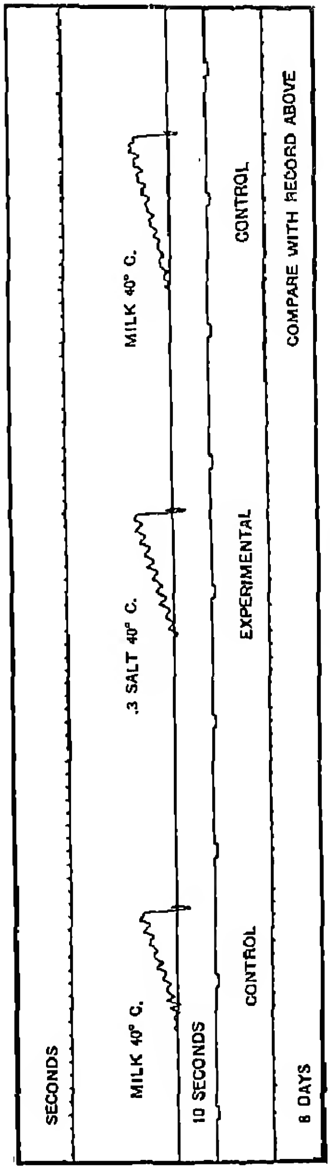
Records 1 and 2 facing this page are for the same infant, 2 being a direct continuation of 1, and show:

1. That milk at a temperature of 40° C. was administered, then .900 salt solution at 40° C., then milk at 40° C., then milk at 40° C., then .300 salt solution at 40° C., and then milk at 40° C.
2. That no differential reaction was made to .300 salt solution at 40° C.
3. That a pronounced differential reaction was made to .900 salt solution at 40° C. (The threshold for salt dilution for infant Kie was found to be .450 per cent showing that the infant reacted differentially to a difference in salt solution of .150 per cent.)
4. That the differential reaction to salt solution was increased as the percentage of salt in solution was increased.

   (Infant Kie—male, negro—4:10 P.M.—dry, crying—8 days old—humidity 82-70.)



RECORD 1



RECORD 2

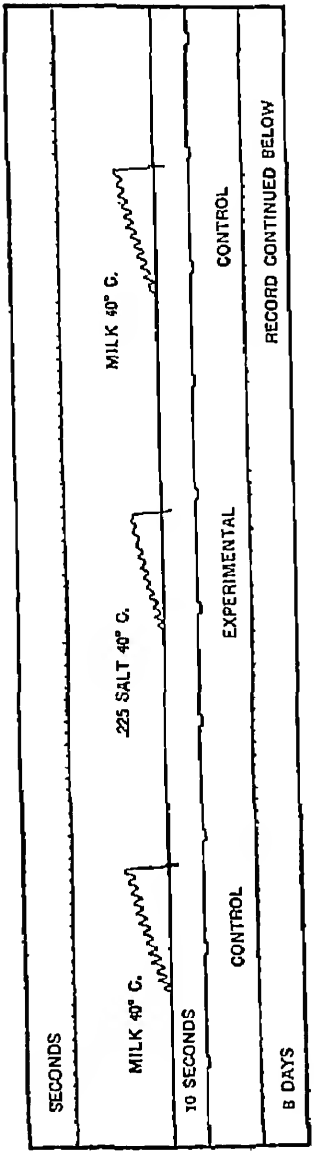
FIGURE 25

Differential Reactions to Salt Solution

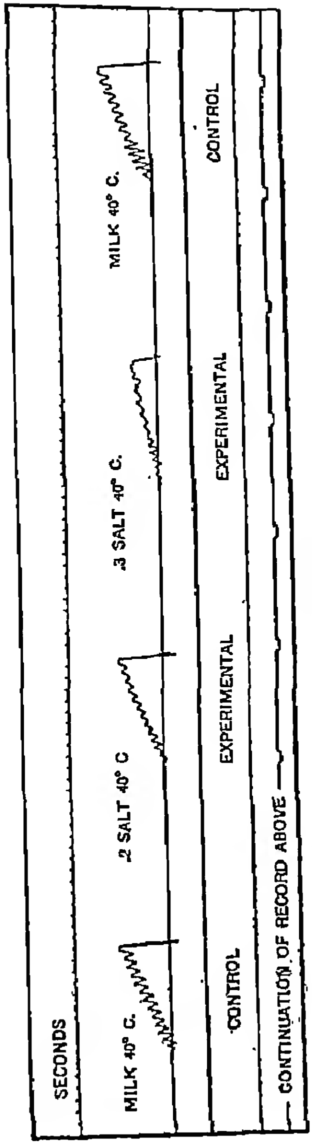
Records 1 and 2 facing this page are for the same infant, 2 being a continuation of 1, and show:

1. That milk at a temperature of 40° C. was administered, then .225 salt solution at 40° C., then milk at 40° C., then milk at 40° C., then .200 salt solution at 40° C., then .300 salt solution at 40° C., and then milk at 40° C.
2. That no differential reaction was made to .200 salt solution at 40° C.
3. That a slight differential reaction was made to .225 salt solution at 40° C.
4. That a pronounced differential reaction was made to .300 salt solution at 40° C.
5. That the threshold for salt solution for infant Fra was .225 per cent.
6. That the infant reacted differentially to a difference in salt solution of .025 per cent.
7. That the differential reaction to salt solution was increased as the percentage of salt in solution was increased.

   (Infant Fra—female, negro—6:30 P.M.—wet, asleep—8 days old—humidity 86-70.)



RECORD 1



RECORD 2

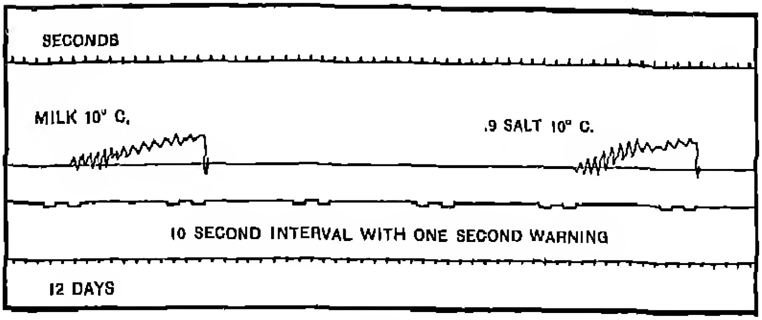
FIGURE 26

Differential Reactions to Salt Solution

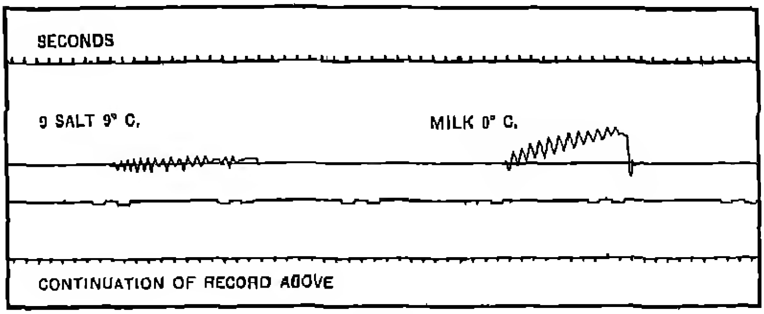
Note: Infant Wis failed to react differentially to .900 salt solution at 40° C., being the only infant tested who failed to do so. Rather than increase the percentage of salt in solution it was decided to compare lower temperature thresholds. The records facing this page were the outcome. No controls are shown, though six were used. (Infant Wis—male, negro—9:30 A.M—dry, crying—12 days old.) Records 1, 2, and 3 show:

1. That milk at a temperature of 10° C., .900 salt solution at 10° C., .900 salt solution at 9° C., milk at 9° C., milk at 8° C., and .900 salt solution at 8° were administered.
2. That there was a slight differential reaction between .900 salt solution at 10° C. and milk at 10° C.
3. That there was a pronounced differential reaction between .900 salt solution at 9° C. and milk at 9° C.
4. That there was a pronounced differential reaction between .900 salt solution at 8° C. and milk at 8° C.
5. That infant Wis reacted differentially between .900 salt solution and milk when the temperatures of both were lowered to 10° C. and that the differential reaction was pronounced at 9° C.
6. That there was a pronounced differential reaction between .900 salt at 9° C. and .900 salt at 10° C.
7. That the infant reacted differentially to a difference of 1° C. in .900 salt solution.

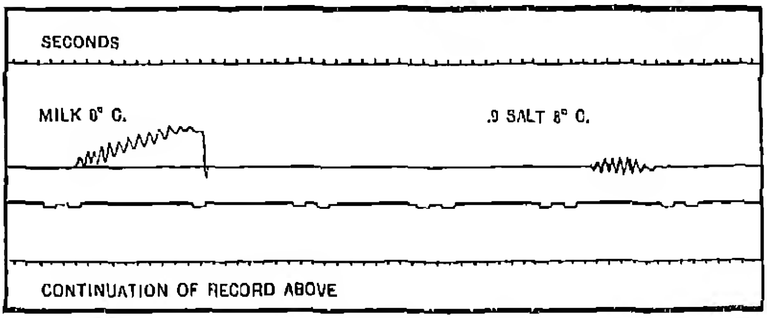
Note: The lower temperature threshold for milk in infant Wis was found to be 5° C. and the upper 65° C.



RECORD 1



RECORD 2



RECORD 3

FIGURE 27

Effect on Sucking Air of Holding Infant's Nose

The record facing this page shows:

1. That the nose was held for 11 seconds while the infant was sucking on air. (The term holding the nose means that the nostrils were compressed so as to make impossible the passage of air.)
2. That four full-sized sucks occurred after the nose was grasped.
3. That after 2 seconds the sucking became very irregular and there was no pressure increase.
4. That after 7 seconds the sucking was resumed and the pressure again mounted.
5. That sucking ceased 3 seconds after the nose was released.

(Infant Fra—female, negro—9:30 A.M.—dry, asleep— 9 days old—humidity 78-66.)

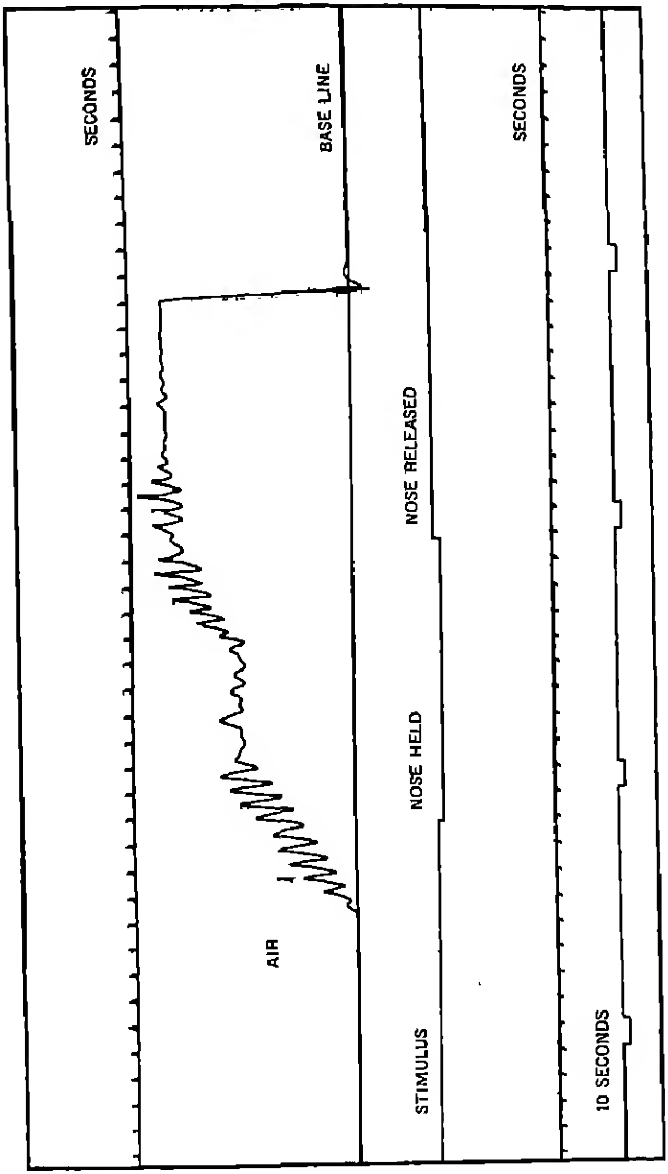

SECONDS
BASE LINE
SECONDS
NOSE RELEASED
NOSE HELD
AIR
STIMULUS
10 SECONDS

FIGURE 28

Effect on Sucking of Pulling Hair or Holding Infant's Nose

Record 1. Effect on sucking air of pulling the infant's head hair. (Infant Cop—male, white—9:50 A.M.—wet, crying—8 days old—humidity 76-63.) This curve shows:

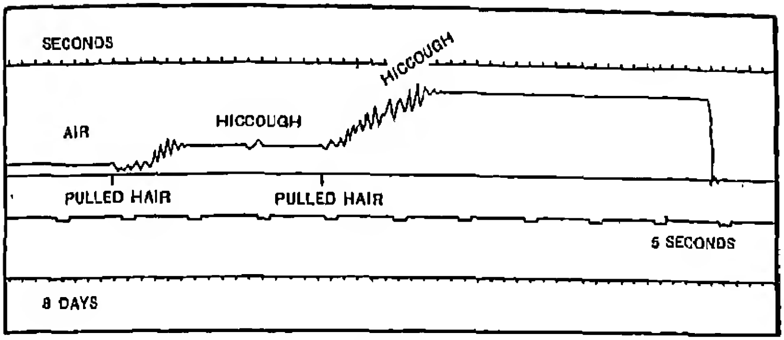
1. That pulling the infant's head hair caused resumption of sucking which had ceased.
2. That the first time the hair was pulled the sucking lasted for 5 seconds.
3. That the second time the hair was pulled the sucking lasted for 8 seconds.
4. That a characteristic record was made on the polygraph tape when the baby hiccoughed while nursing.

Record 2. Effect on sucking milk of holding infant's nose. (Infant Fra—female, negro—9:30 A.M.—dry, asleep—10 days old—humidity 78-66.) This curve shows:

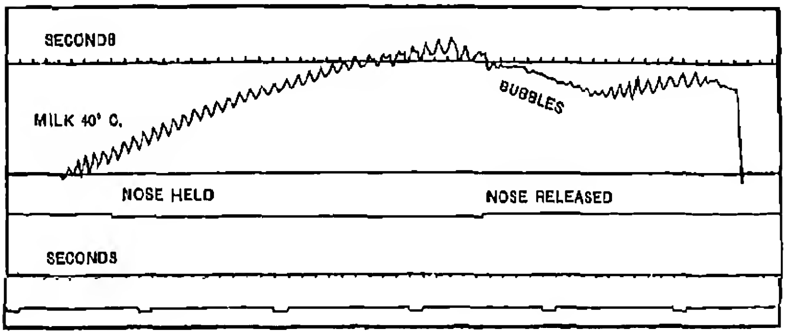
1. That the nose of infant Fra was held for 28 seconds.
2. That for 19 seconds there was no noticeable effect on the sucking.
3. That after 19 seconds the swallows became more pronounced.
4. That after 26 seconds the pressure began to drop.
5. That for 9 seconds after the nose was released there were no sucking movements, and bubbles appeared in the bottle.
6. That 9 seconds after the nose was released sucking was resumed.

Record 3. Effect on sucking milk of holding infant's nose. (Infant Fra—female, negro—3:30 P.M.—wet, crying—9 days old—humidity 84-68.) This curve shows:

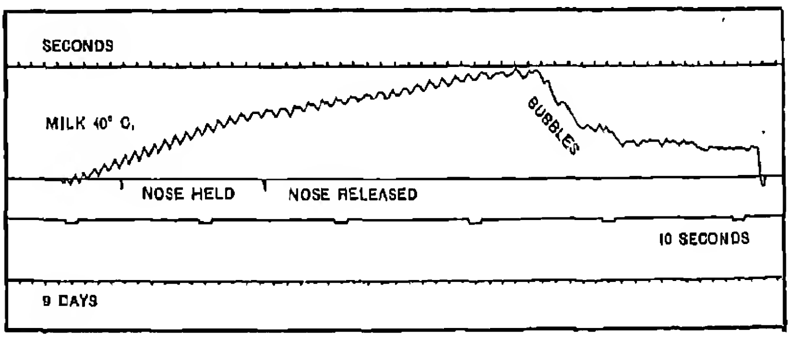
1. That the nose was held for 10 seconds.
2. That there was no change in the sucking behavior while the nose was being held.



RECORD 1



RECORD 2



RECORD 3

FIGURE 29

Effect on Sucking Milk of Turning on a 1000-Watt Lamp, of Pulling the Infant's Hair, or of Pinching Its Toe

Record 1 shows:

1. That for 22 seconds after the bottle was placed in the infant's mouth no sucking occurred.
2. That immediately after a 1000-watt lamp was turned on 2 feet above and 3 feet behind the infant, mouth movements began.
3. That 7 seconds after the light was turned on, coordinated sucking began.

   (Infant Hef—female, white—3:30 P.M.—wet, asleep—8 days old.)

Record 2 shows:

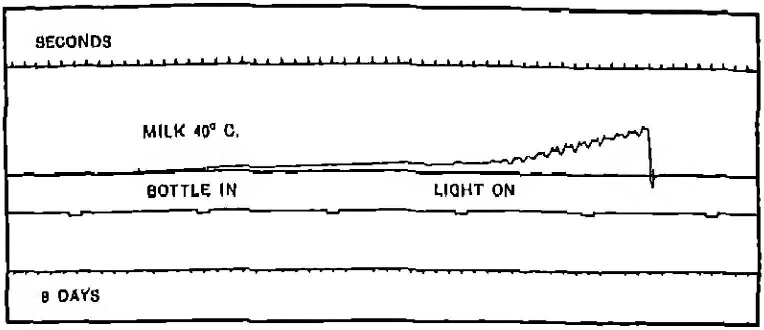
1. That for 37 seconds after the nursing bottle was placed in the infant's mouth no sucking occurred.
2. That 2 seconds after the infant's head hair was pulled, definite coordinated sucking began.

   (Infant Hol—male, white—9:30 A.M.—dry, awake, quiet—4 days old.)

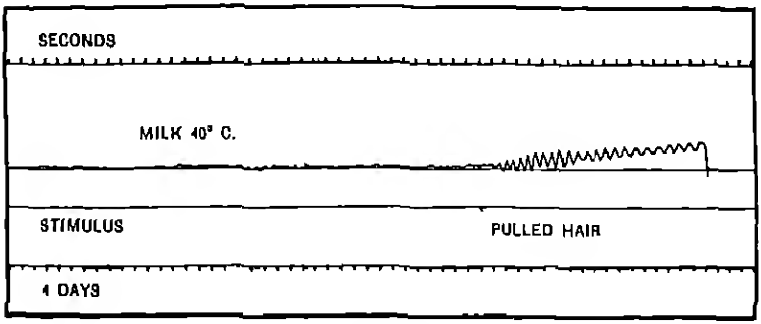
Record 3 shows:

1. That for 10 seconds after the nursing bottle was placed in the infant's mouth no sucking occurred.
2. That 1 second after the infant's large toe of the right foot was pinched, vigorous crying began which continued for 11 seconds.
3. That the vigorous crying stopped abruptly and coordinated sucking began.

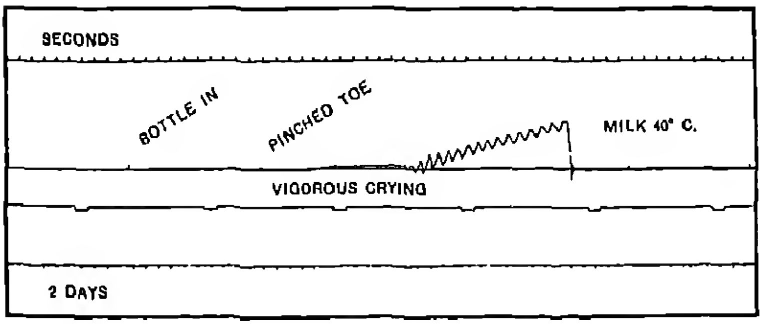
   (Infant Cop—male, white—3:30 P.M.—soiled, asleep—2 days old.)



RECORD 1



RECORD 2



RECORD 3

FIGURE 30

EFFECT ON SUCKING MILK OR AIR OF PINCHING TOE

Record 1 shows:

1. That infant Weh at 1 day of age nursed poorly.
2. That 2 seconds after the large toe of the right foot was pinched, the infant began to whimper, and that this continued for about 2 seconds.
3. That immediately after the infant ceased whimpering, mouth movements began and continued for about 7 seconds.
4. That repetition of the experiment produced substantially the same result.

   (Infant Weh—male, white—9:30 A.M.—dry, awake, quiet—1 day old—humidity 82-72.)

Record 2 shows:

1. That for 12 seconds after the nursing bottle was placed in infant Weh's mouth no sucking occurred.
2. That immediately after pinching its toe, vigorous intake movements occurred for about 2 seconds.
3. That for 6 seconds after the intake movements weak sucking occurred.
4. That 8 seconds after the infant's toe was pinched, strong coordinated sucking began.

   (Infant Weh—male, white—6:30 P.M.—dry, asleep—2 days old—humidity 82-66.)

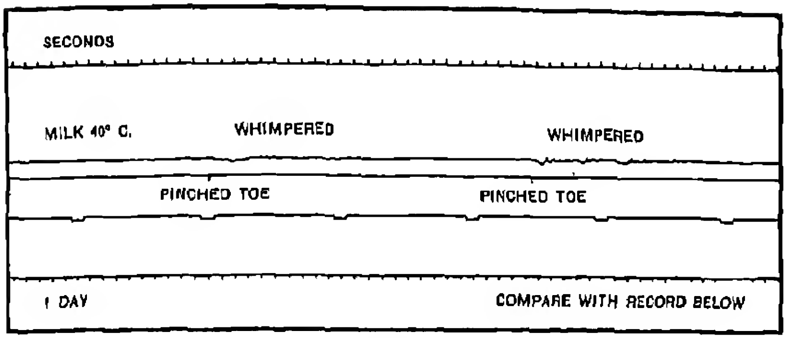
Comparison of Records 1 and 2 shows:

1. That the response to pinching the toe was much greater for infant Weh at 2 days of age than at 1.

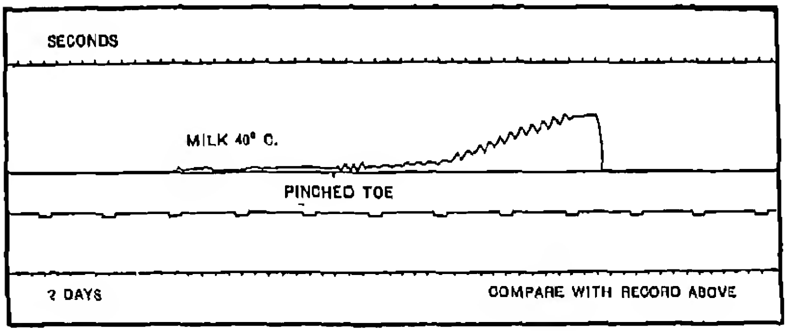
Record 3 shows:

1. That the infant discriminated the empty bottle in about 1½ seconds and refused to suck for 14½ seconds.
2. That 15 seconds after the nursing bottle was placed in the infant's mouth its toe was pinched.
3. That immediately after its toe was pinched, mouth movements began.
4. That 2 seconds after the infant's toe was pinched, vigorous sucking began and continued for 6 seconds, after which the infant refused to suck.

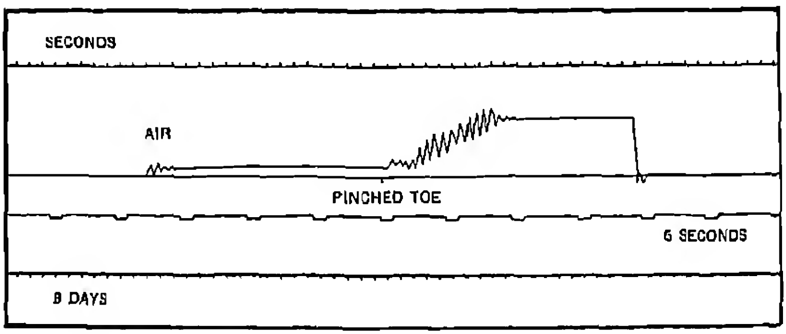
   (Infant Cop—male, white—9:30 P.M.—dry, awake—8 days old—humidity 82-66.)



RECORD 1



RECORD 2



RECORD 3

FIGURE 31

EFFECT OF PINCHING THE TOE ON SUCKING MILK, AIR, AND SALT

Record 1 shows:

1. That for 28 seconds after the nursing bottle containing milk at 40° C. was placed in the infant's mouth no sucking occurred.
2. That 28 seconds after the nursing bottle was placed in its mouth, the infant's toe was pinched.
3. That 2 seconds after its toe was pinched, it began vigorous crying which continued for 8 seconds.
4. That 10 seconds after its toe was pinched, vigorous sucking began and continued for 30 seconds, at which point the bottle was emptied.
5. That after 10 seconds of sucking air the infant refused to continue to suck.

(Infant Cop—male, white—9:30 A.M.—dry, asleep—2 days old—humidity 78-66.)

Record 2 shows:

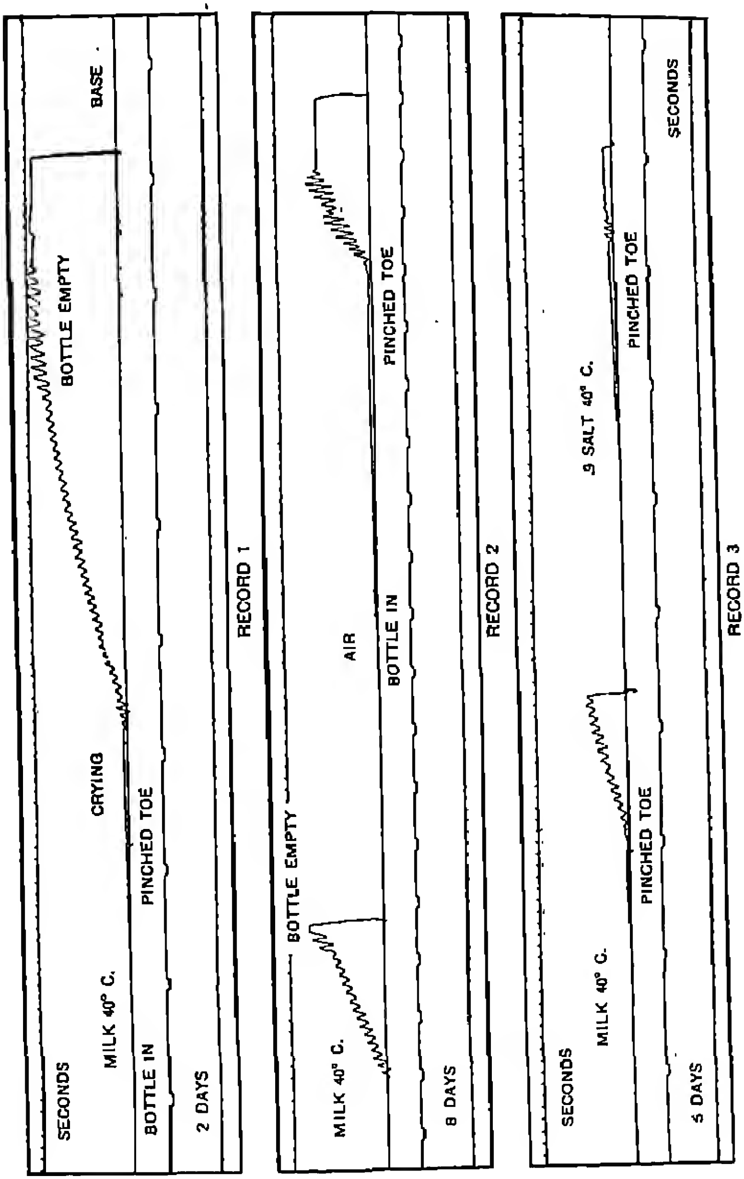
1. That sucking on milk at 40° C. continued until the bottle was emptied.
2. That the infant quickly discriminated the air and refused to suck.
3. That when the infant had refused for 35 seconds to suck on air its toe was pinched.
4. That 4 seconds after its toe was pinched, it began vigorous sucking on air which continued for 9 seconds and then stopped.

(Infant Cop—male, white—9:30 P.M.—dry, awake—8 days old—humidity 82-66.)

Record 3 shows:

1. That for 14 seconds after the nursing bottle containing milk at a temperature of 40° C. was placed in its mouth the infant refused to suck.
2. That 14 seconds after the nursing bottle was placed in its mouth, its toe was pinched.
3. That 2 seconds after its toe was pinched, vigorous sucking began.
4. That the infant refused to suck on .900 salt solution at 40° C.
5. That 14 seconds after the .900 salt solution was placed in its mouth, its toe was pinched.
6. That immediately after its toe was pinched, slight mouth movements began.

(Continued on page 456)


SECONDS
MILK 40° C.
BOTTLE IN
2 DAYS
CRYING
PINCHED TOE
BOTTLE EMPTY
BASE
RECORD 1
MILK 40° C.
BOTTLE EMPTY
AIR
BOTTLE IN
8 DAYS
PINCHED TOE
RECORD 2
SECONDS
MILK 40° C.
PINCHED TOE
5 DAYS
.9 SALT 40° C.
PINCHED TOE
SECONDS
RECORD 3

7. That 4 seconds after its toe was pinched, vigorous sucking movements began, but only three occurred.
8. That differential reactions to .900 salt solution occurred even with the added stimulus of a pinched toe.
(Infant Cop—male, white—3:30 P.M.—dry, crying—5 days old—humidity 86-72.)

Comparison of Records 1, 2, and 3 shows:

1. That in the case of infant Cop pinching the large toe of the right foot produced sucking in the case of milk, air, and salt.
2. That the sucking was greatest and longest continued in the case of milk, next longest in the case of air, and least in the case of salt.

FIGURE 32

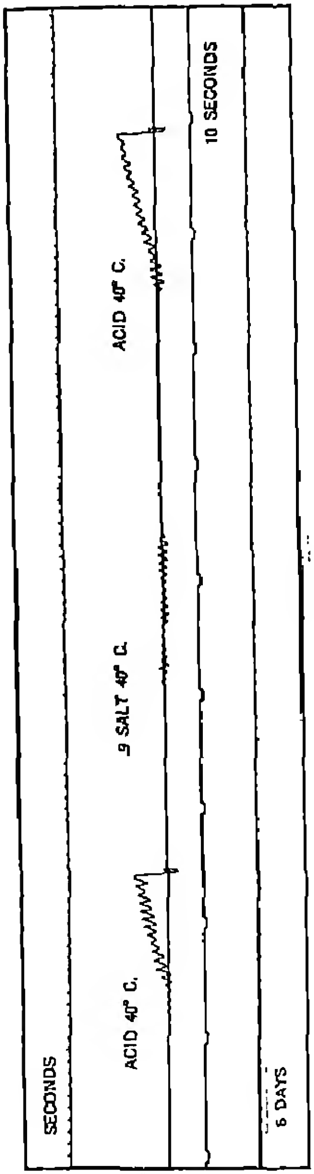
COMPARISON OF SUCKING REACTIONS TO SALT AND TO ACID

Record 1 shows:

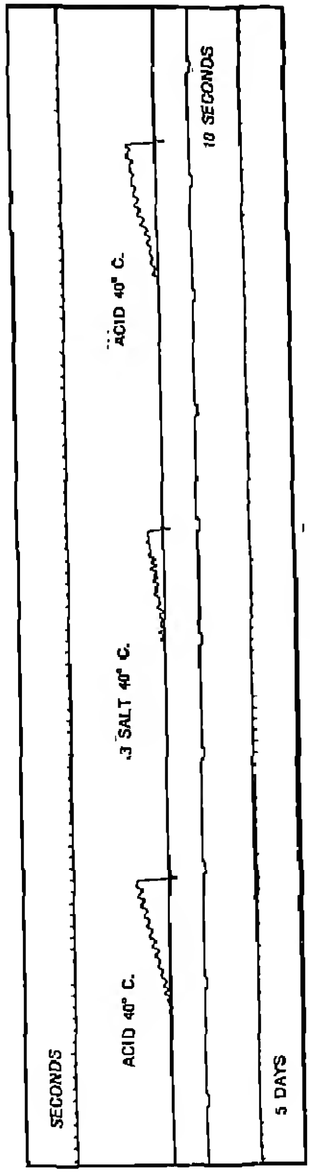
1. That acid at a temperature of 40° C. was administered, then .900 salt solution at 40° C., then acid at 40° C.
2. That a differential reaction occurred between .900 salt solution and acid.
3. That acid acted like a milk control.
(Infant Cop—male, white—9:30 A.M.—dry, asleep—6 days old—humidity 80-66.)

Record 2 shows:

1. That acid at a temperature of 40° C. was administered, then .300 salt solution at 40° C., and then acid at 40° C.
2. That a pronounced differential reaction occurred between .300 salt solution and acid.
3. That acid acted like a milk control.
(Infant Fra—female, negro—3:30 P.M.—soiled, asleep—5 days old—humidity 87-72.)



RECORD 1



RECORD 2

FIGURE 33

Continuous Sucking on Air

Record 1 shows:

1. That in the case of infant Fra sucking on air was intermittent.
2. That no swallows occurred in sucking air.
3. That the sucking was of the intake type.
4. That infant Fra maintained the sucking pressure during rest periods.

   (Infant Fra—female, negro—9:30 P.M.—wet, crying—12 days old—humidity 84-73.)

Record 2 shows:

1. That in the case of infant Swi sucking on air was almost a continuous process.
2. That no swallows occurred in sucking air.
3. That the sucking was of the intake type.

   (Infant Swi—male, white—10:15 A.M.—dry, crying—5 days old—humidity 81-69.)

Record 3 shows:

1. That in the case of infant Cop sucking on air was distinctly intermittent.
2. That no swallows occurred in sucking air.
3. That the sucking was of the intake type.
4. That in the case of infant Cop the pressure tended to drop during the rest periods.

   (Infant Cop—male, white—9:35 A.M.—wet, crying—8 days old—humidity 76-63.)

Note: In each case the sucking on air was continued for 15 minutes with substantially the same result.

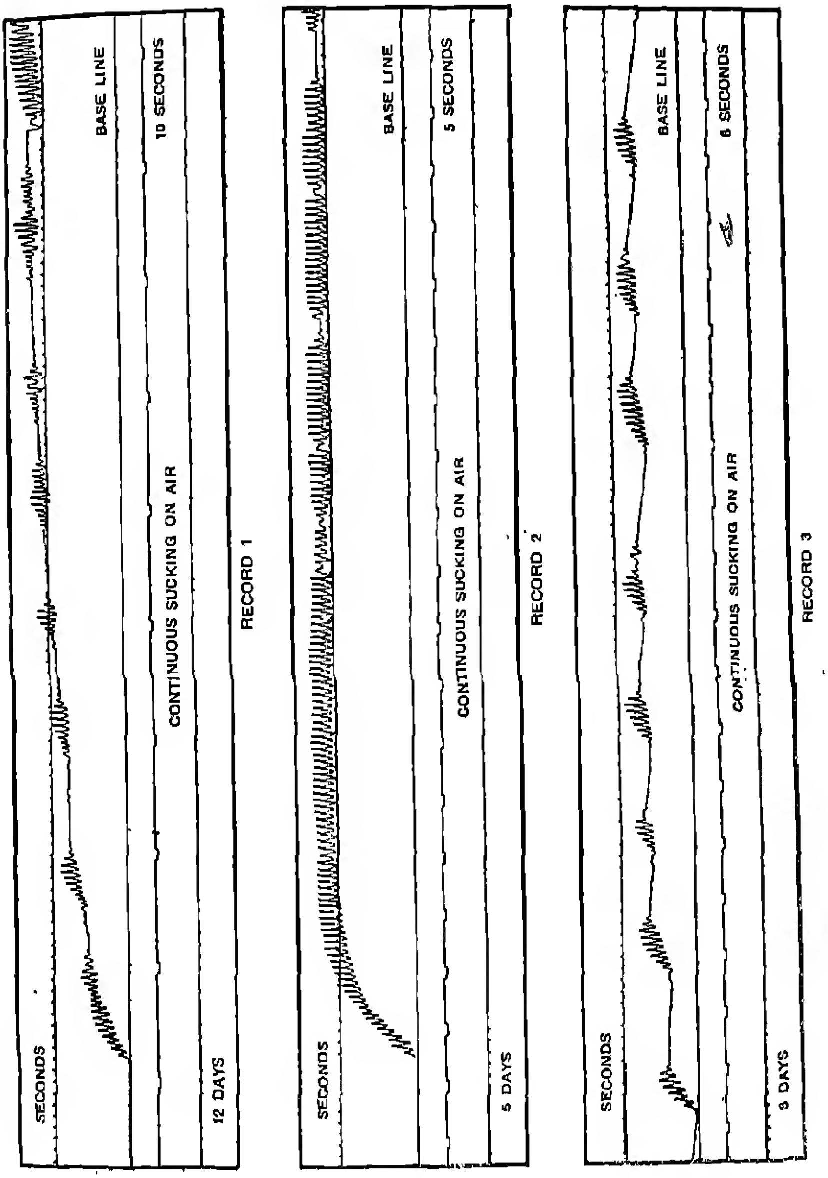

SECONDS
BASE LINE
10 SECONDS
CONTINUOUS SUCKING ON AIR
12 DAYS
RECORD 1
SECONDS
BASE LINE
5 SECONDS
CONTINUOUS SUCKING ON AIR
5 DAYS
RECORD 2
SECONDS
BASE LINE
6 SECONDS
CONTINUOUS SUCKING ON AIR
3 DAYS
RECORD 3

FIGURE 34

Differential Reactions to Air

Records 1 and 2 (Record 2 is a direct continuation of Record 1) show:

1. That milk at a temperature of 40° C. was administered, then air, then milk at 40° C., then air, then milk at 40° C., then air, then milk at 40° C., and then air.
2. That a differential reaction between milk and air occurred.
3. That no swallows occurred in the air record.
4. That the infant learned to discriminate air and refused to suck on the empty bottle. (In Record 2 no sucking at all occurred to air.)

   (Infant Fra—female, negro—9:30 P.M.—wet, crying—10 days old—humidity 86-69.)

Record 3 shows:

1. That milk at a temperature of 40° C. was administered, then air, then milk at 40° C., and then air.
2. That no swallows occurred when sucking on air.
3. That the infant failed to discriminate air. (This experiment was repeated three times with identical results.)

   (Infant Swi—male, white—10:15 A.M.—dry, crying—5 days old—humidity 81-69.)

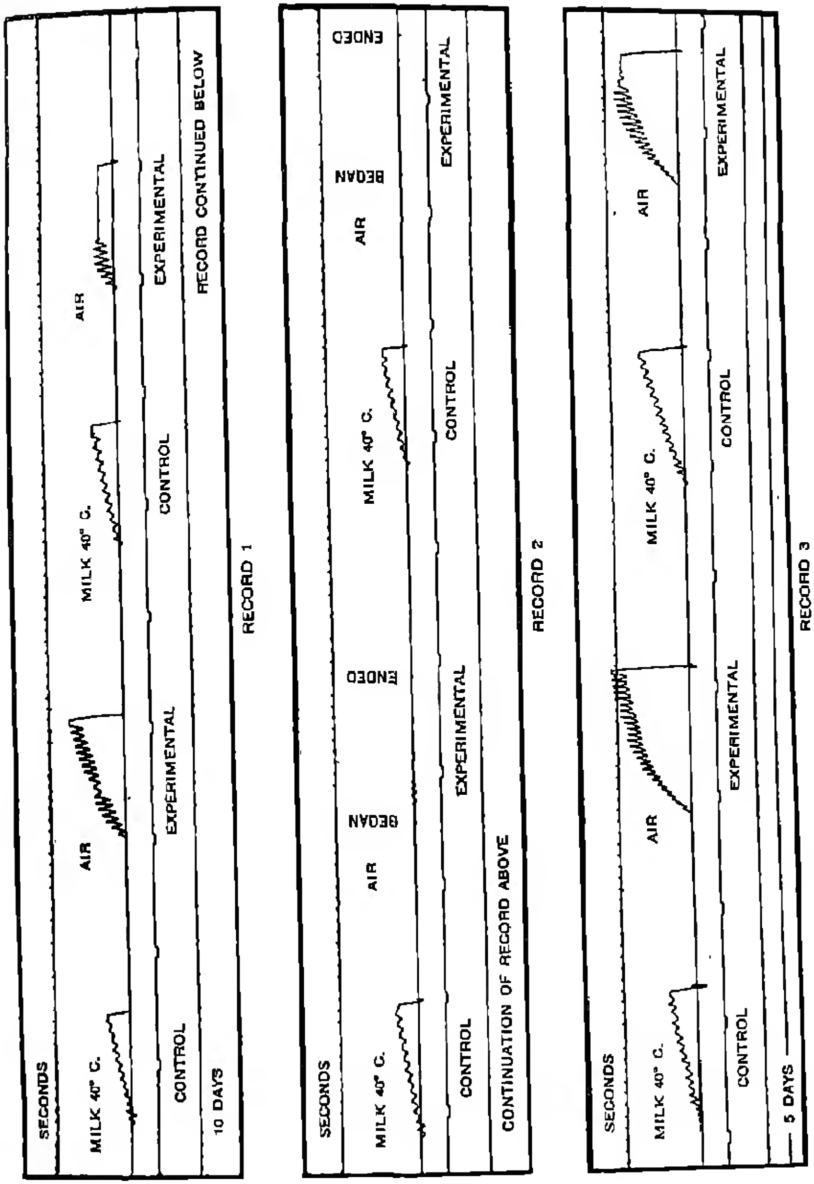

SECONDS
MILK 40° C.
AIR
MILK 40° C.
AIR
CONTROL
EXPERIMENTAL
CONTROL
EXPERIMENTAL
10 DAYS
RECORD CONTINUED BELOW
RECORD 1
SECONDS
MILK 40° C.
AIR
BEGAN
ENDED
MILK 40° C.
AIR
BEGAN
ENDED
CONTROL
EXPERIMENTAL
CONTROL
EXPERIMENTAL
CONTINUATION OF RECORD ABOVE
RECORD 2
SECONDS
MILK 40° C.
AIR
MILK 40° C.
AIR
CONTROL
EXPERIMENTAL
CONTROL
EXPERIMENTAL
5 DAYS
RECORD 3

FIGURE 35

Calibration of Abt's Breast Pump

The three records facing this page show:

1. That Setting 3 gave a record which most closely resembles the record of the infant's sucking curve.
2. That Setting 8 gave a record which is distinctly different from that of the infant.

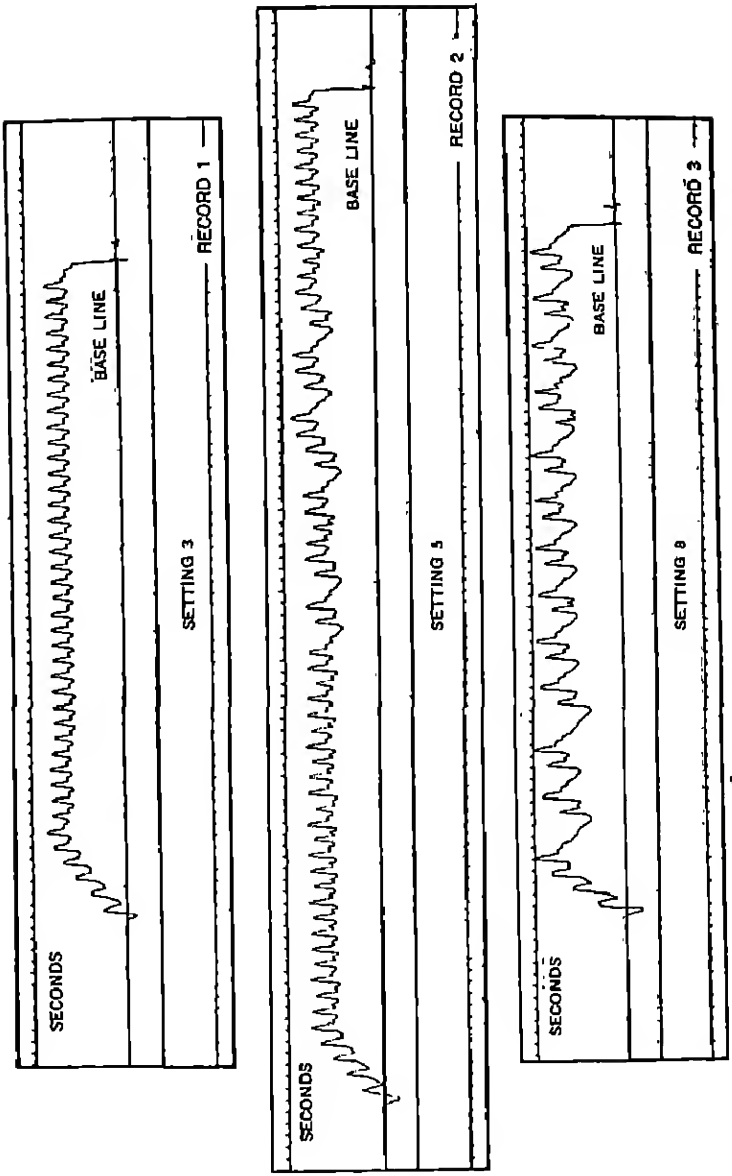
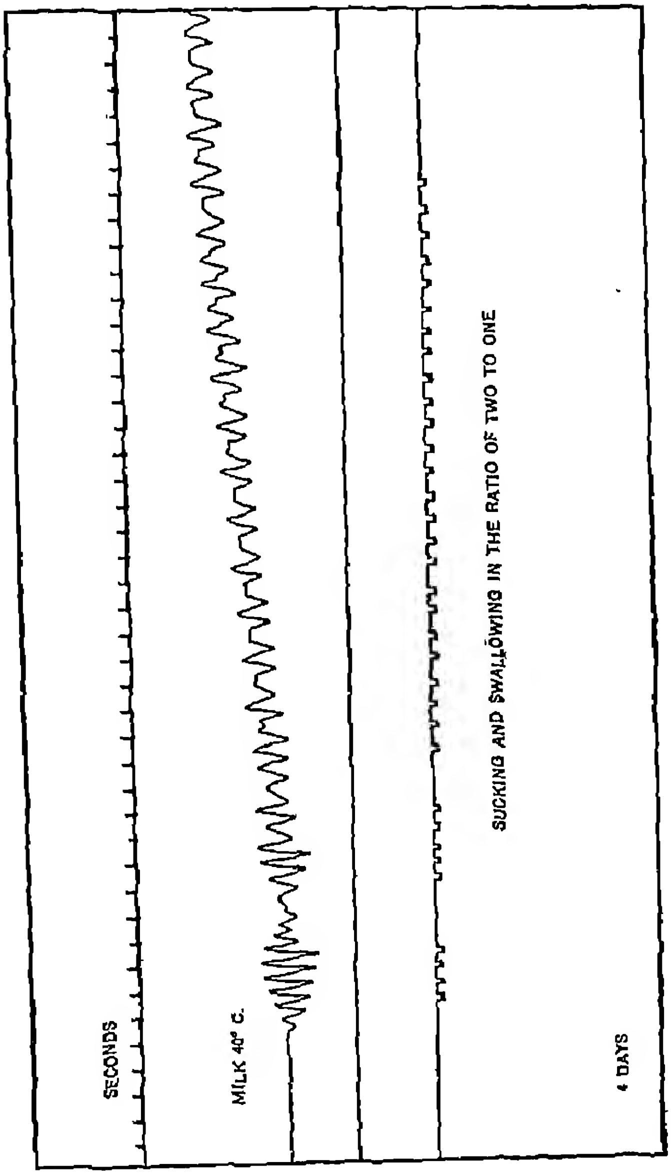

RECORD 1
BASE LINE
SETTING 3
SECONDS
RECORD 2
BASE LINE
SETTING 5
SECONDS
RECORD 3
BASE LINE
SETTING 8
SECONDS

FIGURE 36

SUCKING AND SWALLOWING IN THE RATIO OF 2-1

The record facing this page shows:

1. That for 30 seconds infant Mae maintained a ratio of 2-1 between sucking and swallowing (that is, there would be a suck, and a suck and a swallow, then a suck, and a suck and a swallow, etc.). (This was the only instance in the present investigation where this occurred.)
   (Infant Mae—female, negro—9:30 A.M.—dry, awake—4 days old.)


SECONDS
MILK 40° C.
SUCKING AND SWALLOWING IN THE RATIO OF TWO TO ONE
4 DAYS

IV

CONCLUSIONS AND DISCUSSION

1. Using 450 temperature stimulations on 17 infants, the following temperature thresholds were obtained.

TABLE 3

Infant	Temperature thresholds, °C. Upper	Lower
All	54	18
Als	54	16
Can	52	20
Cop	53	22
Evs	51	19
Fra	50	23
Hef	52	21
Hol	58	15
Jon	54	17
Kic	50	22
Lyn	51	19
Mac	58	14
She	50	22
Swi	56	17
Weh	50	19
Wis	65	5
Wls	52	19

2. Large individual differences in thresholds were found but thresholds for the same infant tended to remain constant over the period of the investigation.

3. Differential reactions to temperatures of 55° and 15° C. were secured as early as the second day (8 infants).

4. Using 937 salt stimulations on 14 infants, the

following points at which differential reactions to salt were obtained were secured.

TABLE 4

POINT AT WHICH
DIFFERENTIAL REACTION TO SALT CEASES

Infant	Strength of salt solution in percentages .900	.450	.300	.225	.200
Als	R.D.*	Failed†	Failed	Failed	Failed
Can	R.D.	R.D.	R.D.	Failed	Failed
Cop	R.D.	R.D.	R.D.	Failed	Failed
Evs	R.D.	R.D.	Failed	Failed	Failed
Fra	R.D.	R.D.	R.D.	R.D.	Failed
Hef	R.D.	R.D.	R.D.	Failed	Failed
Kie	R.D.	R.D.	Failed	Failed	Failed
Lyn	R.D.	R.D.	R.D.	Failed	Failed
Mae	R.D.	R.D.	Failed	Failed	Failed
She	R.D.	Failed	Failed	Failed	Failed
Swi	R.D.	R.D.	R.D.	Failed	Failed
Weh	R.D.	R.D.	Failed	Failed	Failed
Wis	R.D.	R.D.	Failed	Failed	Failed
Wls	Failed	Failed	Failed	Failed	Failed

**R.D.* means reacted differentially
†*Failed* means failed to react differentially

5. Differential reactions to .900-per-cent salt solution were secured as early as the second day (5 infants).

6. Facial expressions of disgust occurred only with differential reactions, but differential reactions occurred 95 per cent of the time without marked facial expressions.

7. For 12 infants differential reactions to temperatures above 50° C. were found to be identical with certain differential reactions below 23° C.

8. The differential reactions secured were not of an all-or-none character but proved to be gradual devi-

ations from the control curves, becoming more marked as the experimental temperatures were raised or lowered as compared with the controls and as the percentage of salt solution was increased.

9. The discriminatory reactions begin with a slight break in the curve, and increase up to the point where very vigorous avoidance movements are made and the child cries lustily.

10. Five distinct types of differential reactions were classified.

11. In threshold determinations, from 6 to 8 seconds may elapse before the differential reaction commences. (Such instances show the inadequacy of the medicine-dropper technique.)

12. Swallowing is determined by the amount of food in the mouth. It is never present in sucking air, and the first 3, 4, or 5 sucks when sucking milk are not accompanied by swallows.

13. Immediately after the bottle is empty, swallowing ceases though sucking continues (shown in 100 per cent of the cases where the bottle was emptied).

14. The recorded pressure under which sucking occurs is a function not only of the feeding reaction itself but also of the ease with which the material in the nursing bottle flows through the nipple.

15. Sucking movements may occur without any pressure rise.

16. The nature of the sucking curve depends in part upon the kind of nipple used.

17. The most vigorous and long-continued sucking is done by hungry, awake babies.

18. The feeding reaction in a hungry, crying baby is often disorganized at first.

19. If the infant has been crying apparently from hunger, there is very often a pronounced jerk of the head as the bottle is presented.

20. For five of the infants the 3-hour interval between feedings was too short for hunger.

21. The moderately full baby is a better discriminator than the very hungry infant.

22. Sucking becomes disorganized as the baby becomes full.

23. Satiety is indicated by:

a. Frequent occurrence of rest periods.

b. Decreased amplitude of the sucking curve.

c. Decreased or even released pressure.

d. Disorganization of the sucking response.

e. A special evidence of satiety is the necessity for forcing open the mouth so that it may receive the nipple. (It is interesting in this connection that the baby sucks contentedly once the nipple is in the mouth, though it may struggle violently against having it placed there.)

24. The changes in the sucking curve which occur with satiety show that the infant makes different responses to a full and to an empty stomach and that food alone is not the complete stimulus.

25. A "full" baby becomes drowsy and goes to sleep.

26. The large toe of the right foot of 17 moderately full infants was pinched 164 times with the result that sucking began in 100 per cent of the cases.

27. The hair of the heads of 17 moderately full infants was pulled 115 times with the result that sucking was resumed in 100 per cent of the cases.

28. Three infants were suddenly dropped 4 inches a total of 20 times, and in each case sucking which had stopped was resumed.

29. Pulling the hair of the head, pinching the toe, or suddenly dropping the infant always produced longer continued sucking on milk than on air (17 infants).

30. Pinching the toe always caused sucking on salt but never more than 4 sucks (6 infants).

31. Holding the nose of the infant while he sucked air did produce a modification in the sucking after 4 seconds (4 infants, 12 stimulations).

32. Holding the nose of the infant while he sucked milk did not produce a modification in the sucking curve even though the nose was held 15 seconds (3 infants, 12 stimulations).

33. In 100 per cent of the cases there were no differential reactions to acid milk (3 infants, 20 trials).

34. For 17 infants there were no differential reactions to glucose.

35. In 100 per cent of the cases there were no differential reactions to sterile water (82 stimulations on 15 infants).

36. In 100 per cent of the cases, involving 17 infants, differential reactions were made when sucking on air (604 stimulations).

37. Ten infants learned to discriminate air. Only one failure occurred in the 11 cases tested.

38. In 604 instances in which 17 infants were permitted to suck on air no swallows occurred.

39. Ten infants sucked on air continuously for 15 minutes after their regular feeding and were quiet until the next feeding period (30 stimulations).

40. The first time the infant is presented with the feeding situation, it often makes excellent sucking responses, but these last only for a brief time (in 8 infants only 4, 5, 6, or 7 coordinated sucks occurred). In one there were no coordinated sucks, and in another coordinated sucking continued for 60 seconds.

41. In the case of one infant sucking was present, but the infant was unable to coordinate the sucking and swallowing, with the result that most of the milk flowed out the corners of the mouth and there was considerable coughing and choking. This condition gradually improved, and disappeared by the sixth day.

42. Infants often "learn" to keep their food down, i.e., much vomiting occurs at first, but less and less occurs as they become older.

43. Five infants which at first refused the bottle opened their mouths and appeared eager to receive the bottle on the fourth and fifth days.

44. Individual variations from one feeding to another are less than the variations from one individual to another.

45. One of the evidences of development in the feeding reaction with age is the increasing ease with which the nipple is placed in the mouth.

46. Movement of the head toward a tactual finger stimulation on the cheek is increased with age.

47. Nystagmus occurred on the day of birth in 100 per cent of the cases tested (5 infants).

48. The present apparatus and technique may be used to determine temperature thresholds and differential taste reactions in lower animals.

49. The Moro reflex may be released by sudden dropping. Note: The dropping technique with the present quantitative records of the feeding reaction lends itself to a differential study of the Moro reflex which is not possible with the standard technique. The standard technique described by Moro follows: "If the young infant is placed on a pillow and the pillow is struck on each side, at first both arms spread apart symmetrically, then approach one another with somewhat jerking motions."

50. Irwin's (17) (1930) "mass activity" disappears immediately after the nipple of the nursing bottle is placed in the infant's mouth.

51. Kashara (18) (1916) found that sucking curves became irregular when temperatures below 20° and above 40° C. were used. In the present investigation 17 infants were given 450 temperature stimulations, and the lowest upper threshold was 50° C. (See the results summarized under Conclusion 1.) This difference in results may be accounted for on the basis of the fact that Kashara used only 2 infants and 2 stimulations or else on the basis of the fact that he used infants 3 months of age.

52. Mrs. Nelson (23) (1928) found that 8° C. gave the most reaction, and 43° C. the least. In the present investigation 43° C. gave the most reaction, and 8° C.

the least. This result can be reconciled with that of Mrs. Nelson, for it is really supplementary. When Mrs. Nelson found that 8° C. gave the most reaction, what that really meant was that no feeding reaction but rather vigorous avoidance movements ensued. On the other hand, 43° C. sets the baby for sucking, and avoidance reactions are reduced to a minimum. If the sucking does not occur, it is because the feeding situation is not complete, i.e., there is no nipple in the mouth.

53. Pratt, Nelson, and Sun (27) (1930) found that "the infants reacted less strongly to the temperatures which are warmer than body temperature than to those which are colder" (p. 167). This result, which is not verified in the present investigation, is easily accounted for. In none of the 17 infants tested were differential reactions made to temperatures of 33°, 43°, or 48° C. Differential reactions were made in 16 infants to temperatures of 8° and 13° C. Ten infants reacted differentially to 53°, one to 23°, 11 to 18°, and 16 to 13° C. Pratt, Nelson, and Sun used temperatures of 8°, 18°, 23°, 33°, 43° 48°, and 53° C. Temperatures 43°, 48°, and 53° C. were classified as above body temperature, and 33°, 23°, 18°, 13°, and 8° C. as below. *Thus they used 4 temperatures to which infants react differentially below body temperature, and only one to which infants react differentially above body temperature.* Also the one differential stimulus above body temperature was very weak, being a borderline temperature, whereas 8° and 13° C. were very strong, and 18° C. alone comparable to the 53° C.

54. Pratt, Nelson, and Sun have concluded: "The

irth represents an organism in which differ-
ias proceeded to the point where there are many effectors and receptors. Its behavior, however, is generalized; that is, stimulation of almost any group of receptors by almost any kind of stimulus will lead to a response in almost any part of the organism. The reaction tends, however, to manifest itself most strongly in that part of the organism which is stimulated, and from there spreads out with decreasing intensity to the other segments of the body" (p. 208).

The results of the present investigation indicate that this statement should be modified to read that stimulation of almost any group of receptors by almost any kind of stimulus will lead to a response in almost any part of the organism which is set to respond. For example, turning on a bright light, pinching the infant's toe, pulling the head hair of the infant, or suddenly dropping the infant results in sucking provided the nipple is in the infant's mouth and the infant is moderately full.

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LES RÉACTIONS DIFFERENTIELLES AUX STIMULI DE GOÛT ET DE TEMPÉRATURE CHEZ LES NOUVEAU-NÉS

(Résumé)

L'absence des réponses verbales chez les nouveau-nés a restreint l'investigation de ces problèmes précisément qui sont la base du comportement des adults. Si l'on pouvait obtenir quelque chose pour remplacer de telles réponses, on ouvrirait un nouveau domaine et éclaircirait beaucoup de problèmes pas encore formulés même.

En cherchant un processus objectif qui pourrait servir comme remplacement partiel du moins de ce comportement verbal, on a développé une nouvelle technique expérimentale comprenant l'emploi d'un mécanisme fondamental du comportement, la réaction à la nourriture, comme indicateur des réponses de l'enfant à la stimulation contrôlée. Cette technique consiste en une comparaison des réactions de sucer à divers stimuli expérimentaux avec une réaction de sucer comme contrôle, toutes les courbes étant enregistrées objectivement. On a employé le lait à une température de 40°C. comme contrôle. On a administré celui-ci pendant 10 secondes. Après un délai de 20 secondes le mélange expérimental (l'eau stérile, la glucose de 6 pour cent, une solution de sel de 0,900, de 0,450, de 0,300, de 0,225 pour cent, ou le lait à des températures au-dessus ou au-dessous de 40°C.) a été administré pendant 10 secondes. Ensuite après un intervalle de 20 secondes on a administré le contrôle encore une fois. On a continué ce processus jusqu'à ce qu'on a donné du moins six contrôles. Puisque les contrôles ont été identiques, on a interprété n'importe quelle déviation de la courbe de contrôle par la courbe expérimentale comme une réaction différentielle. L'ordre de la présentation des stimuli expérimentaux et de celle des contrôles a été continuellement varié pour éviter les erreurs d'espace-temps et comme contrôle de l'adaptation positive et négative.

L'appareil employé a enregistré automatiquement le temps, les courbes de sucement, et les changements du volume de pression trouvés dans la réaction de nourriture. Il s'est composé d'un système de manomètre à tubes; d'un appareil d'enregistrement composé d'un polygraphe, d'un soufflet métallique, et d'une très légère plume barographique Bristol à encre; d'un appareil spécial d'enregistrement du temps; et d'une bouteille spéciale pour la nourriture.

On a étudié dix-sept enfants depuis la naissance pendant les douze premiers jours de la vie. On a observé chaque enfant pendant quatre périodes de nourriture chaque jour. On a apporté l'enfant à la salle expérimentale 15 minutes avant l'heure de nourriture et l'y a gardé 15 minutes après l'heure de nourriture et pendant ce temps on l'a observé constamment. On a employé seulement un enfant à la fois de sorte que la durée de l'investigation a été de plusieurs mois. On a employé un total de 27.831 stimulations expérimentales et 2975 de contrôle.

On a obtenu des seuils de température élevée et non élevée au cas de tous les enfants étudiés et des seuils différentiels de goût au cas de 14 enfants. On a trouvé de grandes différences individuelles de seuils mais les seuils du même enfant ont tendu à rester constants pendant la durée de l'investigation. On a analysé la nature des réactions différentielles et cinq types distincts ont été classifiés. Ces réactions différentielles n'ont pas été de la classe "tout-ou-rien" mais se sont montrés des déviations graduelles des courbes de contrôle, devenant plus marquées comme les températures ont été élevés ou baissées comparées avec les contrôles et comme le

pourcentage de la solution de sel est devenu plus grand. On présente les données objectives obtenues dans ces expériences dans la forme d'impressions à l'eau forte sur zinc des notations originales non retouchées.

JENSEN

DIFFERENZIERENDE REAKTIONEN AUF GESCHMACK- UND TEMPERATURREIZE BEI NEUGEBORENEN SÄUGLINGEN

(Referat)

Die Abwesenheit von Sprachreaktionen bei neugeborenen Säuglingen hat die Untersuchung gerade jener Probleme, die die Basis der Tätigkeit Erwachsener bilden, beschränkt. Könnte man einen Ersatz finden, [illegible]ur solche Reaktionen, so würde sich ein neues Forschungsfeld eröffnen, und [illegible]s würden viele Aufgaben behelligt werden, die noch nicht einmal formul[illegible]iert worden sind.

Im Nachforschen nach einem objektiven Verfahren, dass wenigs[illegible]tens teilweise als Ersatz für solche Sprachreaktionen dienen könnte, w[illegible]urde ein neues experimentelles Verfahren entwickelt, welches die Verwendu[illegible]ng eines grundlegenden Tätigkeitsmechanismus (behavior mechanism)—des [illegible] Essreflexes (feeding reflex)—als Anzeiger (indicator) der Reaktionen de[illegible]s Säuglings auf kontrollierte Reizung in Anspruch nimmt. Dieses Verfahren [illegible] besteht aus der Vergleichung von Saugreaktionen auf verschiedene experi[illegible]mentelle Reize mit einer kontrollierten Saugreaktion, wobei alle Kurven o[illegible]bjektiv registriert wurden. Milch mit einer Temperatur von 40 Grad C [illegible] wurde als Kontrollstoff verwendet. Diese wurde 10 Sekunden lang gegeben[illegible]. Nach 20-Sekunden Pause wurde 10 Sekunden lang die Versuchsmischung [illegible] gegeben. Diese bestand aus sterilem Wasser, einer 6-prozentigen Glukos[illegible]ösung, einer Salzlösung von .900, .450, .300, oder .225 Prozent, oder Milc[illegible]h bei Temperaturen über oder unter 40 Grad C. Nach 20-Sekunden Pause [illegible]wurde dann wieder die Kontrollmischung gegeben. Dieses Verfahren [illegible]urde fortgesetzt, bis wenigstens sechs Mal die Kontrollmischung geg[illegible]eben worden war. Da die Kontrollmischung immer die selbe blieb, wurde [illegible] jede Abweichung der Versuchskurve von der Kontrollkurve als differenzie[illegible]ende Reaktion gedeutet. Die Ordnung der Darbietung sowohl der Vers[illegible]uchs- wie der Kontrollreize wurde beständig variirt. Durch diese Vari[illegible]rung wollte man Raum-Zeitirrtümer vermeiden (space-time errors) und [illegible]eine Kontrolle (check) der positiven und negativen Anpassung erhalten.

Der verwendete Apparat registrierte automatisch den Zeitverbrauch, [illegible]die Kurven des Saugens (sucking curves), und die in der Essreaktion in E[illegible]inspruch genommenen Änderungen des Drucks und der Menge (pressu[illegible]re-volume changes). Er bestand aus: einem Manometerrohrsystem (ma[illegible]o-meter tube system); einem Registrierungstell (recording unit), der [illegible]us einem Polygraph, einem metallenen Blasebalg, und einer sehr leich[illegible]en Bristol'schen barographischen Tintenfeder (Bristol barographic ink pe[illegible]n) bestand; einem besonderen Intervallmesser (interval timer); und ei[illegible]er besonderen Saugflasche (nursing bottle).

Es wurden 17 Säuglinge von der Geburt durch die ersten 12 Tag[illegible]en hindurch untersucht. Es wurde jeder Säugling jeden Tag während vi[illegible]er Essperioden beobachtet. Der Säugling wurde 15 Minuten vor der Fü[illegible]tterung in das Versuchszimmer gebracht, und noch 15 Minuten nach de[illegible]r Fütterung dort gehalten. Diese ganze Zeit hindurch wurde er beobachte[illegible]t.

Man machte nur an einem Kind zu einer Zeit Versuche; die Forschungszeit erstreckte sich also über mehrere Monate. Es wurden im Ganzen 2731 experimentelle und 2975 Kontrollreizungen gegeben.

Bei allen Säuglingen, die untersucht wurden, wurden die oberen und unteren Temperaturschwellen registriert (upper and lower temperature thresholds), und es wurden bei 14 Säuglingen Differenzierungsschwellen für Geschmack (differential thresholds for taste) erhalten. Man fand grosse individuelle Unterschiede in den Schwellen, aber die Schwellen des selben Kindes neigten dazu, über die Periode der Untersuchung hindurch konstant zu bleiben. Die Beschaffenheit der in Einspruch genommenen differenzierenden Reaktionen wurde analisiert, und es wurden fünf separate Typen klassifiziert. Diese differenzierenden Reaktionen betrugen sich nicht als entweder vollständig gegenwärtig oder vollständig abwesend, d.h., als "entweder-oder" Reaktionen (all-or-none reactions), sodern erwiesen sich als allmähliche Abweichungen von den Kontrollkurven, die mit Erhöherung oder Erniedrigung der Temperature im Vergleich mit den Kontrollen ausgeprägter wurden, wie ebenfalls mit Erhöherung des Prozentsatzes der Salzlösung. Die in diesen Untersuchungen erhaltenen objektiven Befunde werden in der Form von Zinkradierungen der originellen unberührten Registrierungen dargeboten.

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